NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

AN ANALYSIS OF
THREE APPROACHES TO THE HELICOPTER PRELIMINARY
DESIGN PROBLEM

by

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March 1984

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REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER

2. GOVT ACCESSION NO.

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
An Analysis of Three Approaches to the Helicopter Preliminary Design Problem

5. TYPE OF REPORT & PERIOD COVERED
Master's Thesis
March 1984

6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s)
Allen C. Hansen

8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Naval Postgraduate School
Monterey, California 93943

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS

11. CONTROLLING OFFICE NAME AND ADDRESS
Naval Postgraduate School
Monterey, California 93943

12. REPORT DATE
March 1984

13. NUMBER OF PAGES
116

14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Sensitivity
Preliminary Helicopter Design
Carpet Plots
HESCOMP

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)
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a graphical solution is developed to meet the design criteria of the helicopter. In the third, an overview of Boeing Vertol's Helicopter Sizing and Performance Computer Program is given. The computer routines which enable a person to access HESCOMP on the Naval Postgraduate School main frame IBM system are also provided.

An Analysis of Three Approaches to the Helicopter Preliminary Design Problem

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MASTER OF SCIENCE IN AERONAUTICAL ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL
March 1984

ABSTRACT

Three methodologies from which to approach the problem of preliminary helicopter design are explored in this paper. The first is a sensitivity analysis of the basic helicopter performance equations. The purpose here is to ascertain where reasonable simplifications can be made that do not seriously degrade the accuracy of the results. The second is a graphical parametric design method, known as Carpet Plots. In this method a graphical solution is developed to meet the design criteria of the helicopter. In the third, an overview of Boeing Vertol's Helicopter Sizing and Performance Computer Program is given. The computer routines which enable a person to access HESCOMP on the Naval Postgraduate School main frame IBM system are also provided.

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ACKNOWLEDGMENT

I would like to acknowledge the invaluable assistance of Professor Donald M. Layton in this endeavor. His encouragement and support greatly contributed to making this both an interesting and worthwhile experience.

I. INTRODUCTION

A. GENERAL

The helicopter design process, the subject of numerous articles and studies is an evolving discipline that borders on being an art. A successful design must balance the user's needs and desires against practical capabilities.

With the introduction of composite materials and new technologies, principally in rotor and engine performance, significant advances have been made in helicopter capabilities. In some instances, the performances of hybrid helicopter designs rivals that of a similarly sized conventional aircraft. For example, the YVX, a joint Boeing-Bell venture, will have the hover and low speed capabilities of a helicopter while being able to cruise at 300 knots.

Viable commercial and military helicopter designs are only thirty years old. The first major use of helicopters occurred during the Korean conflict. To put this in perspective, the first large scale use of conventional type aircraft was in World War I.

Helicopter design can proceed on a number of different levels, ranging from comprehensive computer design programs to preliminary analysis using simplifications of the basic performance equations. Each has its merit and place. Computer-aided design provides a great deal of data.

Generally, these programs integrate aircraft configuration sizing, performance and weight calculations in an iterative process. An example of a computer design program for helicopters is the Helicopter Sizing and Performance Computer Program [HESCOMP], orginally developed by Boeing-Vertol for NASA. This program is currently used as a wide number of institutions conducting studies in helicopter design.

On the opposite end of the spectrum would be sensitivity design studies using the performance equations. Surprisingly accurate simplications of these equations can be made. This provides the designer with an excellent method for doing first cut preliminary helicopter sizing at a low cost.

B. OBJECTIVE

This report is an investigation of several of the methods employed in the preliminary design of a helicopter. Conceptually, the report can be divided into three parts. In the first section, a sensitivity analysis of the basic performance equations is performed. The purpose here is to ascertain where reasonable simplications can be made that do not seriously degrade the accuracy of the result.

In the second section a graphical method of doing parametric design studies, known as Carpet Plots, is developed. This method allows the user to formulate a graphical solution matrix to meet the design criteria specified for the helicopter. Carpet Plots are

particularly instructive since they give visual insight into the interplay of the various design parameters.

In the last section, an overview of HESCOMP is given. Programs are developed which enable a person to access HESCOMP on the Naval Postgraduate School Main Frame IBM system.

II. SENSITIVITY ANALYSES OF BASIC HELICOPTER EQUATIONS

A. DESCRIPTION OF PROBLEM

In preliminary helicopter design, there are a number of instances where a quick first cut analysis would be extremely helpful. This is especially true in determining the preliminary size of the helicopter required to meet the specifications.

Historically, there are a number of variables in the performance equations of helicopters which may be treated as constants. This may allow for significant simplifications and aid in the preliminary design process.

In this section, a sensitivity analysis of the performance equations is done. In a sensitivity analysis, each parameter [or variable] is varied in order to determine its effect on the equation. Variables which are shown to have little effect may be treated as constants and the equation simplified accordingly.

B. SOLIDITY

Solidity, σ , is the fraction of the disk area that is composed of blades. It is a function of b , the number of blades, of a constant cord, c , at a radius, R:

$$\sigma = \frac{bc}{\pi R} \tag{2.1}$$

C. DISK LOADING:

Disk loading is defined as the ratio of the weight to the total area of the rotor disk.

$$DL = \frac{\text{WEIGHT}}{\text{AREA}} = \frac{W}{A} = \frac{W}{\pi R^2}\ [\text{lb/ft}^2] \tag{2.2}$$

D. POWER LOADING

Power loading is the ratio of weight to input power.

$$PL = \frac{W}{P_{in}}\ [\text{lb/hp}] \tag{2.3}$$

In a hover, thrust equals weight; this allows us to rewrite the power loading for the hover condition as

$$PL = \frac{T}{P_{in}} = \frac{\text{ROTOR THRUST}}{\text{ROTOR HORSEPOWER}}\ [\text{lb/hp}] \tag{2.4}$$

E. COEFFICIENT OF THRUST AND POWER

The coefficient of thrust, C_T , is a non-dimensional coefficient which facilitates computations and comparisons:

$$C_T = \frac{T}{A\rho V_T^{\,2}} = \frac{T}{\pi R^2 \rho (\Omega R)^2} \tag{2.5}$$

Similarly, a coefficient of power, C_p , has been established as:

$$C_p = \frac{P}{A\rho V_T^{\,3}} = \frac{P}{\pi R^2 \rho (\Omega R)^3} \qquad (2.6)$$

No significant simplifications can be made to either of these coefficients. However, it should be observed that the coefficient of thrust is inversely proportional to the square of the rotor tip velocity, while the coefficient of power is inversely proportional to the cube.

Assuming all other factors being equal, increasing the rotor tip velocity from 600 fps to 700 fps [an increase of 16.7 percent] will have the following result on these coefficients.

$$C_T = \frac{T}{A\rho V_T^{\,2}}$$

$$= \frac{T}{A\rho(1.167)^2} \qquad (2.5)$$

$$= \frac{T}{A\rho(1.361)}$$

The coefficient of thrust is reduced by 26.9 percent.

Similarly, for the coefficient of power:

$$C_P = \frac{P}{A\rho V_T^{\,3}}$$

$$= \frac{P}{A\rho(1.167)^3} \tag{2.6}$$

$$= \frac{P}{A\rho(1.589)}$$

The coefficient of power is reduced by 37.1 percent.

F. HOVER POWER

The total power in a hover is made up of two terms, profile power, P_o, and induced power, P_i.

Utilizing black element theory the profile power required to hover can be expressed as:

$$P_o = \frac{1}{8}\,\sigma_r\,\overline{C}_{do}\,\rho\,A(\Omega R)^3 \tag{2.7}$$

The induced power predicted by momentum theory is:

$$P_i = V_{in}\,T$$

$$= \frac{T^{3/2}}{\sqrt{2\pi\rho R^2}} \tag{2.8}$$

The total power required to hover is:

$$P_T = P_i + P_o \tag{2.9}$$

$$P_T = \frac{T^{3/2}}{\sqrt{2\pi\rho R^2}} + \frac{1}{8}\sigma_r \overline{C}_{do} \rho A(\Omega R)^3 \qquad (2.10)$$

Donald M. Layton in <u>Helicopter Performance</u>, [Ref. 1], found that for the optimum hover power, the induced power is equal to twice the profile power. The analysis was performed in the following manner.

By assuming constant weight, density, solidity, and an average profile drag coefficient, as well as a fixed rotational velocity, equation (2.10) reduces to

$$P = \frac{C_1}{R} + C_2 R^2 \qquad (2.11)$$

where C_1 and C_2 are constants.

As equation (2.12) shows, profile power increases as the square of the blade radius while the induced power decreases with increasing blade radius.

The optimum hover power with respect to rotor radius can be determined by taking the differential and setting it equal to zero.

$$\frac{dP}{dR} = 0 = -\frac{C_1}{R_2} + 2\ C_2 R \qquad (2.12A)$$

or

$$\frac{C_1}{R} = 2\ C_2 R^2 \qquad (2.12B)$$

which implies

$$P_i = 2\ P_o \qquad (2.12C)$$

G. HELICOPTER SIZING

A simplified relationship between the total power required, gross weight and rotor radius can be developed in the following manner.

The total power required to hover equation for the main rotor was developed in the preceding section and is repeated here for clarity.

$$P_T = P_i + P_o \tag{2.9}$$

$$P_T = \frac{T^{3/2}}{\sqrt{2\pi\rho}} \cdot \frac{1}{R} + \frac{1}{8} \sigma_r \overline{C}_{do} \rho\pi V_{tip}^{3} R^2 \tag{2.10}$$

In a hover, thrust equals weight. Solving equation (2.11) for weight one obtains:

$$W^{3/2} = [P_T - \frac{1}{8} \sigma C_{do} \rho\pi V_T^{3} R^2] \sqrt{\rho A} \tag{2.13}$$

This equation may be further simplified if it is assumed that the density, average profile drag coefficient and tip velocity are constants; these are reasonable assumptions. Historically, the average profile drag coefficient of a helicopter has been approximately 0.01. The operating environment of today's helicopters, especially military, is below 5,000 feet agl. This allows for the use of the standard sea level value for density with little error. Primarily, due to tip mach effects, the upper limit on the rotor tip velocity is in the range of 700 fps.

The resulting equation with these assumptions incorporated into a constant, K, is:

$$W = [47.527\ P_T\ R - K_1\ bc]^{2/3} \qquad (2.13)$$

Equation (2.13) can be further reduced when the order of magnitude of the two terms is considered.

$$47.527\ P_T\ R >> K_1\ bc$$

Thus,

$$W \approx [47.527\ P_T\ R]^{2/3} \qquad (2.14)$$

To determine how accurate this simplification is, the equation is used to approximate the total weight of a number of helicopters for which the parameters are available. As Table 2.1 indicates, the weight approximation formula yields values within six percent of the actual total weight of these helicopters.

H. FIGURE OF MERIT

A figure of merit, FM, has been defined for the helicopter as the ratio of the ideal rotor induced power to the actual power required to hover, with non-uniform induced velocity, tip losses and profile drag power.

TABLE 2.1

HELICOPTER WEIGHT COMPARISON

HELICOPTER	TOTAL GROSS WEIGHT (1000 lbs)	CALCULATED GROSS WEIGHT (1000 lbs)	PERCENT OF ACTUAL GROSS WEIGHT
AH-64	14.66	14.69	101%
UH-1N	14.20	13.74	97%
H-3H	21.00	20.63	98%
S76	10.00	9.90	99%
UH-60A	20.25	19.33	95%
H-54B	42.00	42.00	100%
H-53D	42.00	41.00	98%
H-53E	73.50	69.00	84%

In a hover, the figure of merit may be written as:

$$FM = \frac{1}{\sqrt{2}} \cdot PL \cdot \frac{DL}{\sqrt{\rho}}$$

$$= \frac{CT^{1.5}}{\sqrt{2C_p}} \tag{2.15}$$

The figure of merit is customarilty plotted against the quantity CT/σ. According to Zalesch [Ref. 2], CT/σ, is proportional to the average blade angle of attack and can be used as a measure of rotor efficiency. The curve in Figure 2.1 is based on data from Reference 2 for a typical tail rotor helicopter.

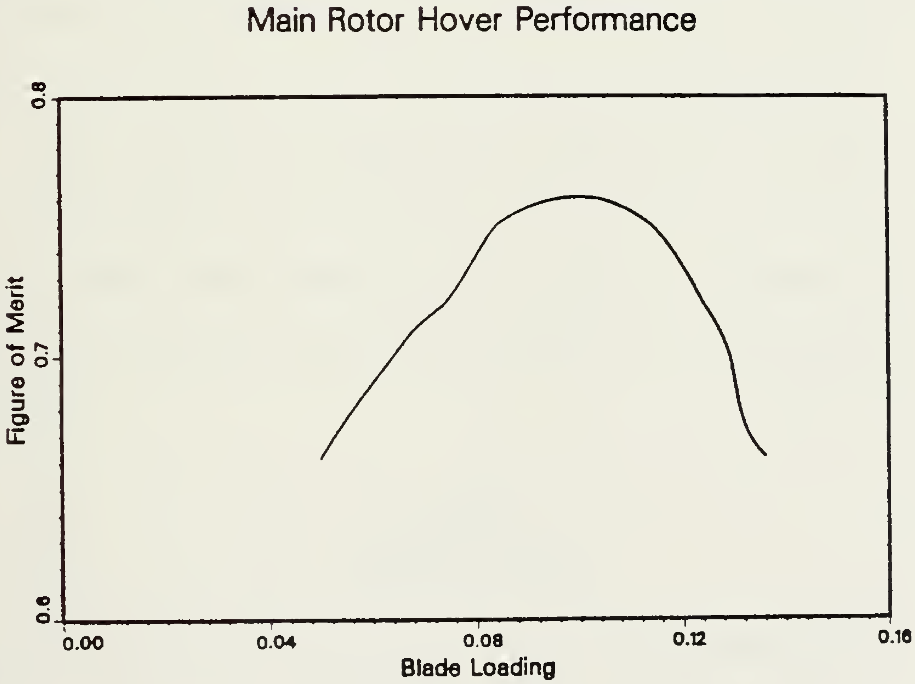

Figure 2.1. FM Versus Blade Loading CT/σ

Previous studies have shown that a figure of merit between 0.70 and 0.80 is considered average.[Ref. 3] If the induced power is between 70 and 80 percent of the total power, the figure of merit will be approximately 0.75.

With the figure of merit limited to values between 0.70 and 0.80, the following simplification can be made, assuming the hover condition of thrust equaling weight and standard sea level conditions:

$$FM = \frac{W^{3/2}}{67.214\ P_T R} \tag{2.16}$$

For Navy helicopter design, the rotor radius has been limited by flight deck spotting constraints to less than 30 feet; the exception to this is the H-3, R = 31 feet and the H-53, R = 36 to 38 feet [depending on the model]. However, these two helicopters work almost exclusively from large air dedicated ships such as the LPH, LHA and CV.

If the small deck operating assumption is made, equation (2.16) can be further simplified to [assuming R = 28 feet]:

$$P = \frac{W^{3/2}}{1881.98\ FM} \tag{2.17}$$

An FM of 0.80 will yield a P to W relationship of:

$$P_T = \frac{W^{3/2}}{1505.58} \tag{2.18}$$

while an M of 0.70 yields a relationship

$$P = \frac{W^{3/2}}{1317.39} \qquad (2.19)$$

If equation (2.17) is solved utilizing the approximate weight relationship developed earlier of

$$W^{3/2} = 47.527\ P_T R \qquad (2.14)$$

a value for the figure of merit of 0.707 is obtained. This is within the historical range of values.

I. TAIL ROTOR SIZING

A historical analysis of typical helicopters [Ref. 3), shows the following empirical relationship for the tail rotor radius

$$R_T \simeq 1.3\ [\frac{GW}{1000}]^{1/2}\ [ft] \qquad (2.20)$$

when comparing the results of this equation with actual tail rotor radius data, it was found that if a multiplication factor of 1.2 is used vice 1.3 a better approximation is obtained. The results are tabulated in Table 2.2.

J. FORWARD FLIGHT POWER CONSIDERATIONS

The total power in forward flight consists of induced, profile and parasite power. If the helicopter is a single rotor vehicle, the tail rotor power should be taken into

TABLE 2.2

TAIL ROTOR SIZING

HELICOPTER	ACTUAL TAIL ROTOR RADIUS [FT]	APPROXIMATION [FT] [2.20]	[2.21]
AH-64	4.6	4.98	4.59
UH-1N	4.3	4.90	4.52
SH-3H	5.3	5.95	5.5
S-76	4.0	4.11	3.79
UH-60A	5.5	5.85	5.4
CH-53D	8.0	8.42	7.78
CH-53E	10.0	11.15	10.29

account, as well as all mechanical losses [transmission, etc.] for accurate calculations. However, a reasonable approximation can be obtained by considering only the main rotor and increasing this power figure by several percent to account for these losses.

Figure 2.2 is a plot of the induced, profile, parasite and total power curves for typical tail rotor helicopter.

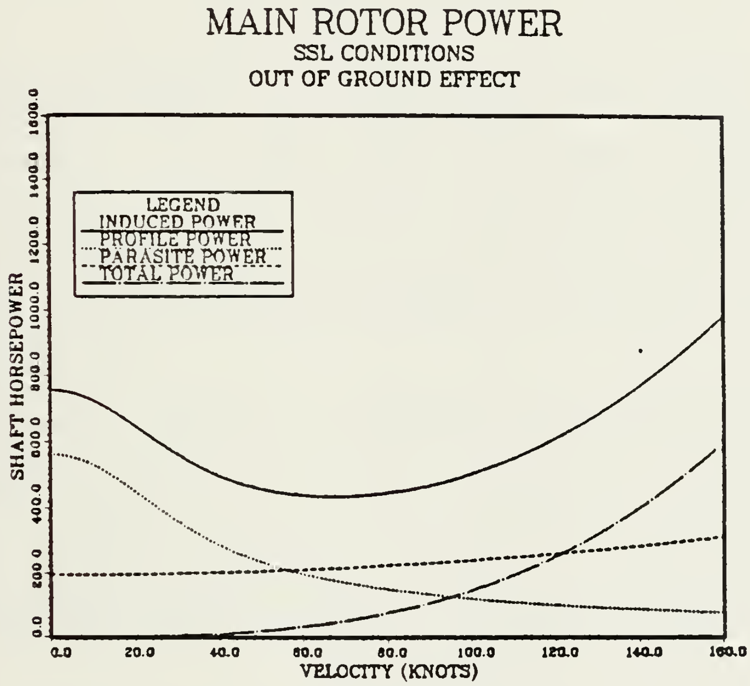

Figure 2.2. Power Required Versus Forward Velocity

The induced power drops off rapidly with increasing forward-velocity, whereas the parasite power increases rapidly.

Parasite power is the power required to overcome the drag forces created by the aircraft's geometry. These drag forces are due to pressure drag and skin friction.

Parasite drag is extremely sensitive to the helicopter's loading. It is generally a minimum for forward flight and increases for sideways flight. Helicopters are generally streamlined for forward flight and the flat plate area is a minimum in this direction. The equation for the parasite power is:

$$P_p = \frac{1}{2} \rho V_f^3 f_f \qquad (2.21)$$

The parasite power is a function of the cube of the forward velocity. As such, with the advent of high speed helicopters a great deal of consideration has been placed on streamlining the geometric shape in order to reduce this power requirement.

Blade element theory is commonly used to develop the profile power equation for forward flight. An excellent development of this equation is given in Reference 1.

The profile power equation in forward flight is:

$$P_{of} = \frac{1}{8} \sigma C_{do} \rho A V_T^3 [1 + 4.3 \mu^2] \qquad (2.22)$$

Equation (2.23) is a function primarily of the main rotor geometry. The variable with the most significance is the rotor tip velocity; increasing the tip velocity from 600 to 700 fps results in a 58.8 percent increase in profile power [assuming other factors are constant].

The induced power is a function of the induced velocity. In a hover, the total flow through the rotor system is induced. As the forward velocity increases, the mass flow rate through the rotor disc increases due to the forward translation of the helicopter. This reduces the induced velocity.

The equation for the induced power requirements at all forward velocities is:

$$P = T \cdot V_{it} \tag{2.23}$$

where

$$V_{it} = \left\{ - \frac{V_f^2/V^2}{2} + \sqrt{\left[V_f^2/2V^2\right]^2 + 1} \right\}^{1/2} . V \tag{2.23a}$$

At high forward velocities, the induced power required can be approximated as:

$$P_i = WV_{it} = \frac{W^2}{2\rho AV_f} \tag{2.24}$$

The total power for forward flight is the sum of the induced, profile and parasite powers.

$$P_T = P_i + P_o + P_p \tag{2.25}$$

$$P_T = T.V_{it} + \frac{1}{8}\sigma\ C_{do}\ \rho\ A\ V_T^{\ 3}[1 + 4.3\ \mu^2] + \frac{1}{2}\rho\ f_f\ V_f^{\ 3} \tag{2.25a}$$

At high forward velocities, equation (2.23) can be substituted into equation (2.25), resulting in:

$$P_T = \frac{W^2}{2\rho A V_f} + \frac{1}{8}\sigma\ C_{do}\ \rho\ A\ V_T^{\ 3}[1 + 4.3\ \frac{V_f}{\Omega R}] + \frac{1}{2}\rho\ f_f\ V_f^{\ 3} \tag{2.26}$$

If one makes the following assumptions:

$$W = \text{const} \qquad C_{do} = \text{const}$$

$$\rho = \text{const} \qquad \sigma = \text{const}$$

$$VT = \text{const}$$

Equation (2.26) reduces to

$$P_T = \frac{K_1}{R^2} + K^2\ R^2 + P_p \tag{2.27}$$

The derivative of equation (2.27) with respect to radius is:

$$\frac{dP_T}{dR} = -\ \frac{2K_1}{R^3} + 2\ K_2\ R \tag{2.28}$$

Setting this equal to zero, one obtains:

$$- \frac{2K_1}{R^3} + 2\ K_2\ R = 0 \tag{2.28a}$$

$$\frac{R}{2} * [- \frac{2K_1}{R^3} + 2\ K_2\ R] = 0 \tag{2.28b}$$

$$\frac{K_1}{R^2} = K_2\ R^2 \tag{2.28c}$$

$$P_i = P_o \tag{2.28d}$$

This defines point of minimum total power required for VMAX range. This corroborates with the results obtained by Waldo Carmona [Ref. 4].

If the total power required is differentiated with respect to forward velocity and is set equal to zero, it can be seen that

$$P_i = 3\ P_o \tag{2.29}$$

or

$$\frac{W^2}{2\rho AV_f} = \frac{3\rho fV_f{}^2}{2} \tag{2.30}$$

Solving this equation for velocity results in:

$$V_f = \left[\left(\frac{W}{A} \quad \frac{A}{3f_f}\right)^{1/2}\right]^{1/2} \quad \text{ft/sec} \qquad (2.31)$$

According to Carmona [Ref. 4], this corresponds to the best endurance velocity.

K. DENSITY EFFECTS ON TOTAL POWER

The effect of density on the total power required in forward flight is as follows:

The general operating altitudes of a helicopter are below 10,000 feet. The corresponding ICAO STANDARD ATMOSPHERE range for density is

$$\rho = 0.0023769 \ [\text{lb sec}^2/\text{ft}^4] \quad \text{SSL}$$

$$\rho = 0.0017553 \ [\text{lb sec}^2/\text{ft}^4] \quad \text{at 10,000 feet}$$

$\rho/\rho SSL$ varies from 1 to .7385.

The effect on the components of P_T are as follows:

Induced Power:

$$1/\rho/\rho SSL \Rightarrow 1 \text{ to } \frac{1}{.7385}$$

This translates to a 35 percent increase in the induced power.

Parasite and Profile Power:

Both parasite and profile powers are directly proportional to the density ratio. Therefore, as you go up in altitude both P_o and P_p are reduced.

III. CARPET PLOT DESIGN STUDY

A. DESCRIPTION OF PROBLEM

Preliminary helicopter design involves one with a wide range of choices. For any given payload and performance specifications, there a number of helicopter designs that satisfy the requirements. The problem in the preliminary design process is narrowing these possibilities and selecting the design which will provide the best helicopter for the mission.

Obviously, the operating environmental constraints help to define the basic configuration. These constraints are usually specified in the Request for Proposal [RFP], in the case of a military helicopter. For example, typical constraints placed on the design of a Navy helicopter are the size of the ship deck and hangar from which it will be operating, the requirement for a blade fold system, dual engine configuration and IFR capability.

Even with these design constraints, there is still a great deal of leeway. In order to insure that the best helicopter design is selected, an appropriate number of solutions satisfying the specifications should be investigated. Since each solution is generally characterized by a different combination of design parameters, the

selection, according to Greenfield [Ref. 5], can best be made through a parametric study which allows for the optimization of many design parameters.

One method of parametric analysis used is Carpet Plots. This method is based on the simultaneous graphical solution of the weight and hover performance equations. To this solution set is added to the environmental constraints to the helicopters size. This effectively brackets the area of acceptable design solutions.

This method assumes that minimum gross weight is the criterion by which the best [or optimum] design parameters are selected.

B. ASSUMPTIONS

1. Airfoil used is a derivative of the NACA 0012 with the following mean approximate values from Reference 5.

a = slope of airfoil section lift curve, $dC_t/d\alpha$, per rad.

$a = 5.73$

δ = blade section drag coefficient

$\delta_0 = .009$

$\delta_2 = .3$

2. a) The tail rotor radius is assumed to be .16 times the main rotor radius [Ref. 5].

b) The distance between the rotors, or tail rotor moment arm, ℓ_{TR} is 1.19R [Ref. 5]. These ratios reflect the values of maximum rotor diameter and overall length specified as size limitations.

3. B = .97. Historical approximation [Ref. 7].

C. METHODOLOGY

In order to properly develop the weight and performance equations required for a carpet plot design study, the payload and performance specifications of the helicopter are needed. This data is used to tailor the equations for the design.

The equations will be developed here for a four-place light helicopter. The equation development procedure is applicable to other size helicopters; the development for a medium helicopter, 20,000 lb weight class, is to be found in Appendix B.

The following specification requirements which are similar to those in Reference 5 will apply to this design:

1. The rotor diameter should be less than 35.2 feet.
2. The overall length should be less than 41.4 feet.
3. The gross weight of the helicopter should not exceed 2,450 lbs.
4. The helicopter should be capable of hovering, out of ground effect at 6,000 feet with an ambient air temperature of 95^{o}F.

5. The useful load at hover shall consist of, as a minimum, 200 lbs for the pilot, 400 lbs of payload and sufficient fuel to give the helicopter up to three hours endurance at sea level conditions.

6. Maximum speed of at least 110 knots using Normal Rated Power, at sea level.

7. Total Power Required at 6,000 feet and 95°F shall be not more than 206.

D. HOVER EQUATIONS

1. The main rotor power required to hover out of ground effect is

Total Main Rotor Power [Hover] = Rotor Profile Power + Rotor Induced Power

$$P_T = \frac{1.13W}{550B\sqrt{2\rho_o}} \sqrt{\frac{DL}{\rho/\rho_o}} + \frac{6WV_T}{4400} \frac{\rho/\rho_o}{C_{LRo}} \left[\delta_0 + \delta_2 \left[\frac{C_{LRo}}{\alpha\rho/\rho_o} \right]^2 \right] \tag{3.1}$$

At an altitude of 6,000 feet and a temperature of 95° , $\rho/\rho_o = .749395$. Therefore, equation (1) can be simplified to:

$$P_{T6000/95^oF} = .035479W[DL]^{1/2} + \frac{.91971}{C_{LRo}} [10]^{-5}(1 + 1.80779\ C_{LRo}{}^2)W\ V_T \tag{3.2}$$

The tail rotor thrust required to counterbalance the main rotor torque is:

$$T_{TR} = \frac{550\ P_T R}{\ell_{TR}\ V_T} = \frac{550\ P_T}{1.19 V_T} \tag{3.3}$$

where ℓ_{TR} has been defined as 1.19R . With R_{TR} defined as .16R , the tail rotor disk loading can be written, using equation (3) as:

$$\begin{aligned} DL_{TR} &= \frac{T_{TR}}{A_{TR}} = \frac{550\ P_T}{1.19 V_T} \frac{1}{\pi(.16R)^2} \\ &= \frac{550\ P_T}{1.19(.0256)V_T} \frac{DL}{W} \end{aligned} \tag{3.4}$$

Greenfield [Ref. 5], in his development, assumes that the tail rotor tip speed is equal to the main rotor tip speed and that $\delta_{TR} = .02$ and $\beta_{TR} = .90$. With these assumptions the equation for the tail rotor power required to hover can be written as:

$$\begin{aligned} P_{T_{TR_{Hover}}} &= 2055.7 \left[\frac{DL}{W\ \rho/\rho_o}\right]^{1/2} \left[\frac{P_{T_{Hover}}}{V_T}\right]^{3/2} \\ &+ \frac{.012605\ P_{T_{Hover}}}{C_{LRTR}} \end{aligned} \tag{3.5}$$

The equation for the tail rotor mean blade lift coefficient can be written as

$$C_{LRTR} = \frac{P_T}{562.5(\rho/\rho_o)} \qquad (3.6)$$

if it is assumed that the tail rotor is designed to counterbalance a sea level main rotor torque equivalent to 90 percent of the installed power.

Substituting equation (3.6) into equation (3.5) one obtains the following expression for hover tail rotor power:

$$P_{T_{TR6000/950}} = 2374.7 \left[\frac{DL}{W} \right]^{1/2} \left[\frac{P_{T_H}}{V_T} \right]^{3/2} + 5.3134 \qquad (3.7)$$

It is assumed that the gear losses amount to 3 percent and that there is a 1 percent cooling power loss, the total brake horsepower required to hover becomes:

$$P_T = \frac{P_{Tm} + P_{TTR}}{96} \qquad (3.8)$$

Empirical studies have shown that the tail rotor power required to hover can be approximated by

$$P_{T_{AC}} \sim .8 \text{ [total horsepower to hover]}$$

This allows one to write the main rotor power required to hover as:

$$P_{Tm} = (.88)(P_{Tm}) \qquad (3.9)$$

Following Greenfield's [Ref. 5] development further, if equations (3.2) and (3.7) are substituted in equation (3.8), one obtains

$$P_{T_{H6000/95^o}} = .036757\ W\ \sqrt{DL}$$

$$+ \frac{.95803}{C_{LRo}} (10)^{-5} [1 + 1.80779\ C_{LRo}{}^2]\ W\ V_T \quad (3.10)$$

$$+ 2473.6 \sqrt{\frac{DL}{W}} \left[\frac{P_{Tm}}{V_T} \right]^{3/2} + 5.5348$$

Utilizing the approximation for tail rotor power, equation (3.9), equation (3.10) can be solved for W (gross weight) as a function of variables V_T (tip speed), DL (rotor disk loading), C_{LRo} (rotor mean lift coefficient) and P_{T_H} (total power to hover).

$$W = \frac{K_1 \left[1 - 411.51 \frac{DL^{3/4}}{V_T{}^{3/2}} \left(1 + K_2 \frac{V_T}{\sqrt{DL}} \right)^{1/2} \right] - K_3}{V_T + K_4 \sqrt{DL}} \quad (3.11)$$

where:

$$K_1 = P_{T6000/90^o} \frac{(10)^5}{K_5} \quad (3.11a)$$

$$K_2 = \frac{.00025929}{C_{LRo}} (1 + 1.80779\ C_{LRo}{}^2) \quad (3.11b)$$

$$K_3 = \frac{553480}{K_5} \tag{3.11c}$$

$$K_4 = \frac{3695.7}{K_5} \tag{3.11d}$$

$$K_5 = \frac{.95803}{C_{LRo}} (1 + 1.80779\ C_{LRo}{}^2) \tag{3.11e}$$

Equation (3.11) has been programmed in Appendix B and solved for tip speeds from 600 to 700 cps and C_{LR} of .3 to .7.

Equation (3.11) is one of the two primary equations used to obtain the data required for a carpet plot design analysis. Generally, the variables V_T, DL, C_{LRo} and P_T, that are required for solution have specific ranges of values, depending on the weight class of the helicopter being designed. The graphical results of equation (3.11) for tip speeds of 600 to 700 fps and mean lift coefficients between .3 and .7 are illustrated in Figure 3.1.

Both the Fortran and Disspla programs, as well as a decision making flow chart are provided in Appendix C to aid in using this method for a design solution.

E. WEIGHT EQUATIONS

Weight equations need to be developed that realistically reflect the sizing class of the helicopter being designed. The evolution is greatly simplified if a specific engine

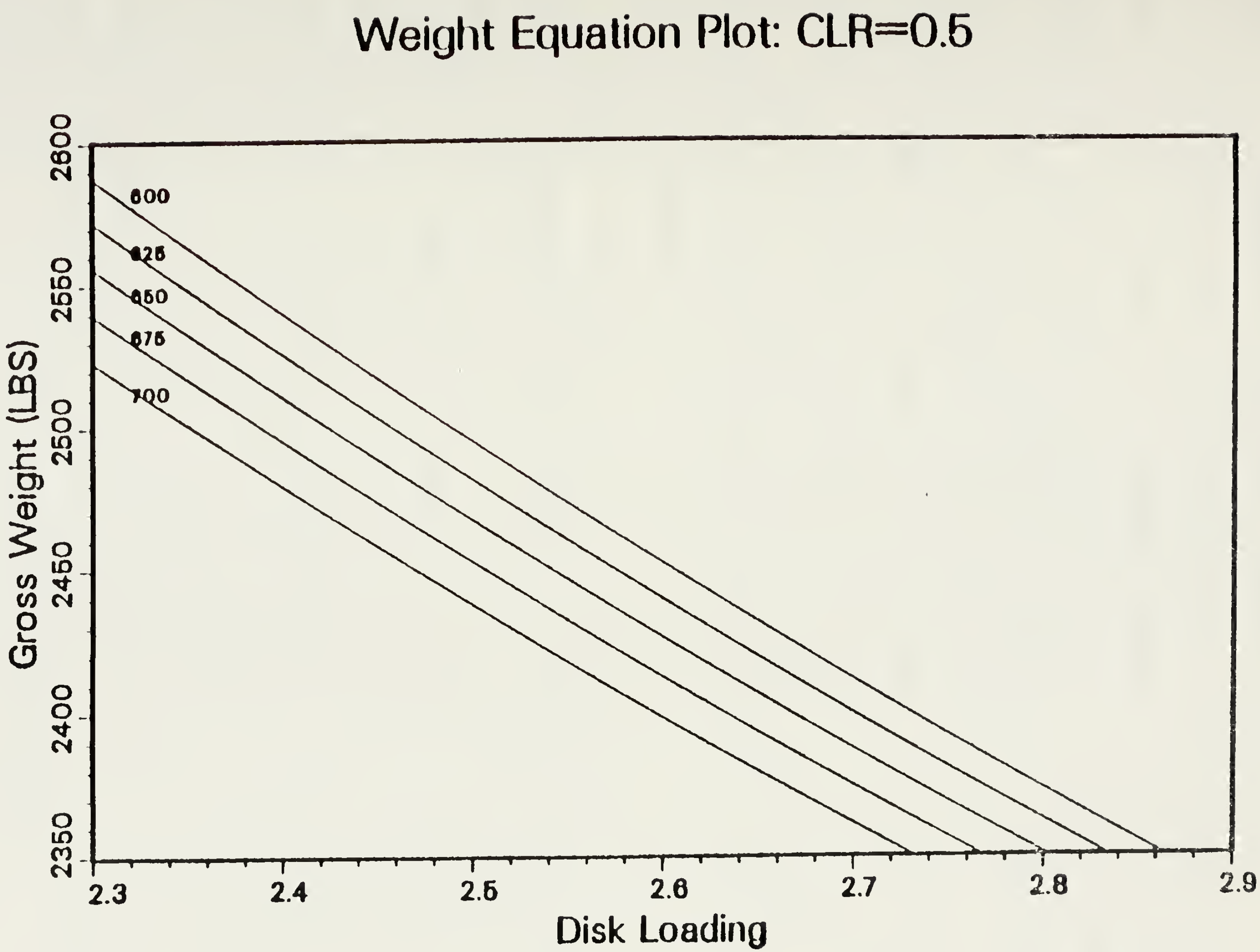

Figure 3.1. Weight Equation Plot: C_{LR} = 0.5

installation [# and horsepower] is assumed, since the weight of a number of components depend only on the installed power; this would include such terms as the engine controls and accessories. Another category would be those components whose weights depend on either the gross weight on two or more of the following in combination: rotor tip speed (V_T), rotor diameter (R), rotor solidity (σ).

The equations developed here are taken from the Hiller Aircraft Corporation Performance Data Report. [Ref. 5] In this report they assumed a specific engine installation, the Allison T-63 with a military power rating at sea level of 250 horsepower.

There is a possible problem of the validity of these weight relationships when applied to different helicopter design categories. However, assuming a specific engine determines a number of the component weights, and thus minimizes the inaccuracies. Using the weight estimation relationships developed in the Helicopter Design Manual [Ref. 2], the engine, control and accessory weight can be calculated and the weight formulas developed here applied to give a representative useful load and empty weight formula for preliminary design analysis. This is done in Appendix C, for a 20,000 pound class helicopter.

The following relations are used to reduce the component weight formulas for the specification helicopter:

$$W/DL = A = \pi R^2 \tag{3.12}$$

$$W/PL = MHP = 250 \tag{3.13}$$

(Military rating for Allison T-63 at sea level.) (PL = Power Loading.)

$$P = \sqrt{A}/V_T \tag{3.14}$$

Using these equations the component weight for the specified helicopter empty weight may be reduced to the following:

Engine, Controls and Accessories		= 617.5 lbs.	
Engine Section Group	$.053[W/PL]^{1.07}$	= 19.5 lbs.	(3.15)
Main Transmission	$10.43 \dfrac{W^{1.295}}{(PL\ V_T)^{.863}}$	$= 1221\ p^{.803}$	(3.16)
Rotor Drive Shaft	$5.56 \dfrac{W^{1.05}}{(PL\ V_T)^{.7}(DL)^{.35}}$	$= 266\ p^{.7}$	(3.17)
Tail Rotor	$32.22 \dfrac{W^{1.14}}{(PL\ V_T)^{1.7}}$	$= \dfrac{17449}{{V_T}^{1.14}}$	(3.18)

The engine, controls and accessories category includes such items as lubrication and oil cooling system, engines, communications, engine controls, engine accessories, instruments starting system, furnishing, flight controls, electrical system and stabilization. These are considered fixed weight items determined from specification of the engine and weight class of the helicopter.

Tail Rotor Gear Box

$$3.7 \frac{W^{.75}}{(PL\ V_T{}^{.5}(DL)^{.25}} = 59.47 \sqrt{P} \qquad (3.19)$$

Tail Rotor Drive Shaft

$$.124 \frac{W^{1.355}}{(PL\ V_T)^{.57}(DL)^{.785}} = 2.886\ P^{.57} \sqrt{A} \qquad (3.20)$$

Body and Gear Landing

$$= 1.91\ W^{.916} + .0294\ W^{.99}$$

Rotor Blade Teetering

$$35.15 \frac{W^{1.185}\sigma^{.33}}{V_T(DL)^{.185}} = 35.15 \frac{W}{V_T} A^{.185}\sigma^{.33} \qquad (3.21)$$

Rotor Blade Artic-ulated

$$19.77 \frac{W^{1.205}\sigma^{.33}}{V_T(DL)^{.205}} = 19.77 \frac{W}{V_T} A^{.205}\sigma^{.33} \qquad (3.22)$$

Rotor Hub Teetering

$$.0088 \frac{W^{1.21}}{DL^{.21}} = .0088\ WA^{.21} \qquad (3.23)$$

Rotor Hub Artic-ulated

$$.00975 \frac{W^{1.21}}{DL^{.21}} = 00975\ WA^{.21} \qquad (3.24)$$

Fuel System $\quad .416$ per gallon capacity $= .0615\ W_F$ (3.25)

where W_F = fuel weight.

The individual component weights may now be combined into a single expression for the helicopter empty weight.

$$W_e = 617.5 + .0617W_F = 1221P^{.863} + 266P^{.7} + \frac{17449}{V_T^{\,1.14}} \tag{3.26}$$

$$+ 58.47\sqrt{P} + 2.886P^{.57}\sqrt{A} + .191W^{.916} + .0294W^{.99}$$

+ appropriate rotor blade and hub weights.

As stated earlier, the design specifications called for a useful load consisting of a pilot (200 lbs), payload (400 lbs) and the required fuel weight (W_F). The fuel weight is calculated for the Allison T-63 in the following manner: endurance of three hours at 85 percent of normal rated powered for the T-63 is 180.2 HP and the specific fuel consumption at this power is .783 lbs fuel/BHP HR. Including an allowance for a three-minute warm-up at NRP and using a 5 percent correction factor on SFC, as specified in Reference 5, the fuel weight becomes:

$$W_F = 3(180.2)(.822) + \frac{3}{60}(212)(777) \tag{3.27}$$

An allowance should also be made for oil plus trapped fuel. This is estimated at 20 lbs.

The total useful load is the sum of the useful load items.

$$W_u = 200 + 400 + 452.6 + 20 = 1072.6 \text{ lbs} \qquad (3.28)$$

A new variable, W_{BAR} , is defined as the sum of the emply weight plus useful load. It is the of equations (3.26) and (3.28).

$$W_{BAR} = 1717.9 + 1221P^{.863} = 266P^{.7} + \frac{17449}{V_T^{1.14}} + 58.47\sqrt{P}$$

$$+ 2.886P^{.57}\sqrt{A} + .191W^{.916} + .0294W^{.99} \qquad (3.29)$$

+ appropriate rotor blade and hub weights.

Equation (3.11) together with equation (3.29) form the basis of a carpet plot design study. These equations are solved simultaneously for W_{BAR} . This solution is best illustrated graphically, as in Figure 3.2. The graph in Figure 3.2 was generated for a specific value of C_{LR} over a range of tip speeds [600 to 700].

F. GRAPHICAL ANALYSIS

Graphs similar to Figure 3.1 are generated for several value of C_{LR} , and are then cross plotted to form Figure 3.2.

The mean lift coefficient, C_{LR} , values are selected based on what is considered the historical average range of

Helicopter Carpet Plots: CLR=0.5

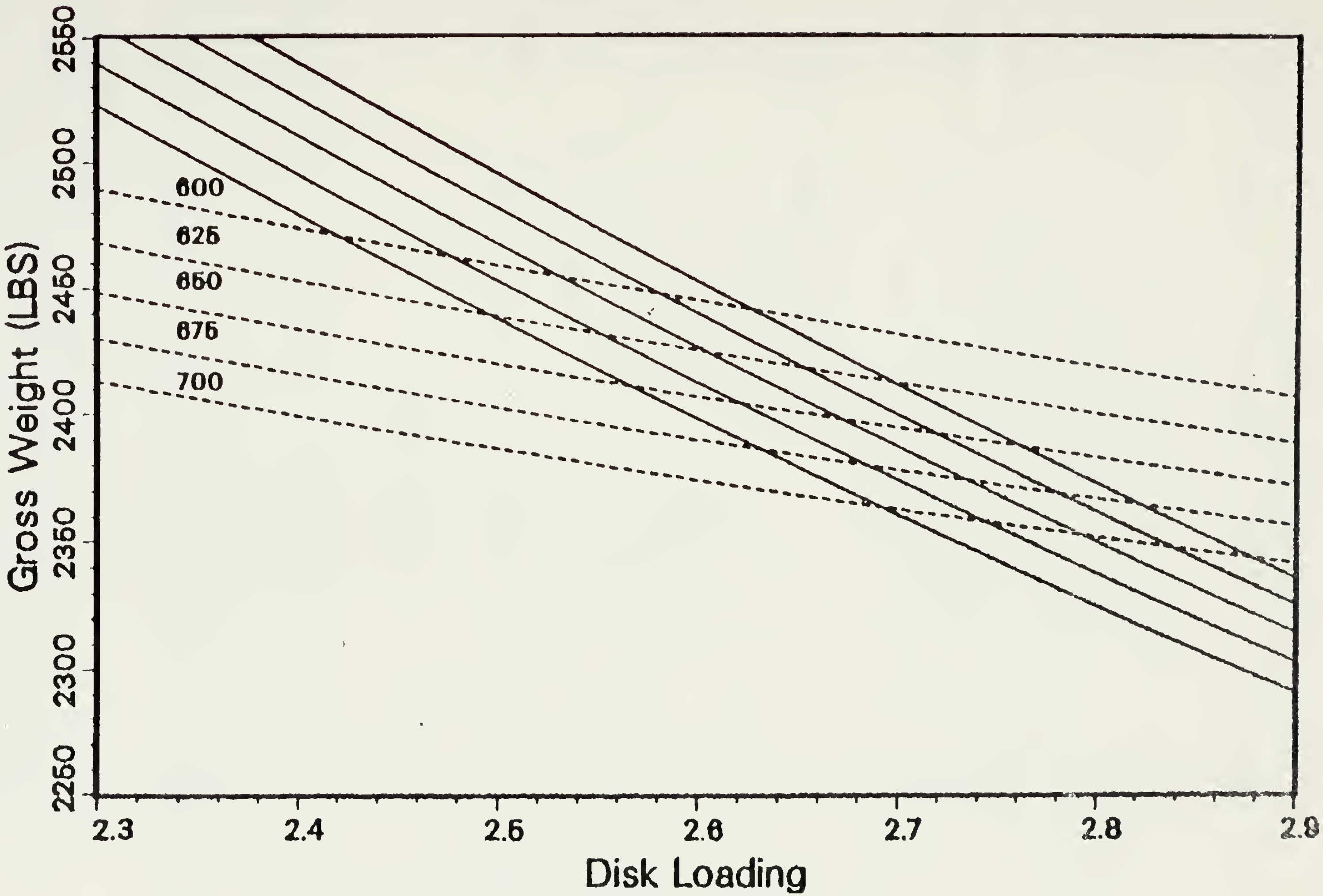

Figure 3.2. Helicopter Carpet Plots: $C_{LR} = 0.5$

values. Figure 3.3 is basic plot for a carpet plot design study. Programs are provided in Appendix D which will generate the required data sets and plots of Figures 3.2 and 3.3.

The solution field depicted in Figure 3.3 is too large to be of great analytic value and as such must be reduced. Three parameters, maximum gross weight, rotor diameter (both specified in the Design Specification) and the aspect ratio can be used to narrow the field of solutions.

1. Rotor Diameter Boundary

A net to exceed value for the rotor diameter is generally given in the design specifications. This limiting value is based on the operating environment of the helicopter. With R max specified, there is a linear relationship between the disk loading and the gross weight.

$$DL = \frac{W}{A} = \frac{W}{\pi R^2}$$

The resulting bracketing of the solution field by applying both the maximum gross weight and maximum rotor diameter limits to the carpet plot are shown in Figure 3.4.

2. Respect Ratio Boundary

It is evident that a further restriction is still necessary to completely define the region of acceptable

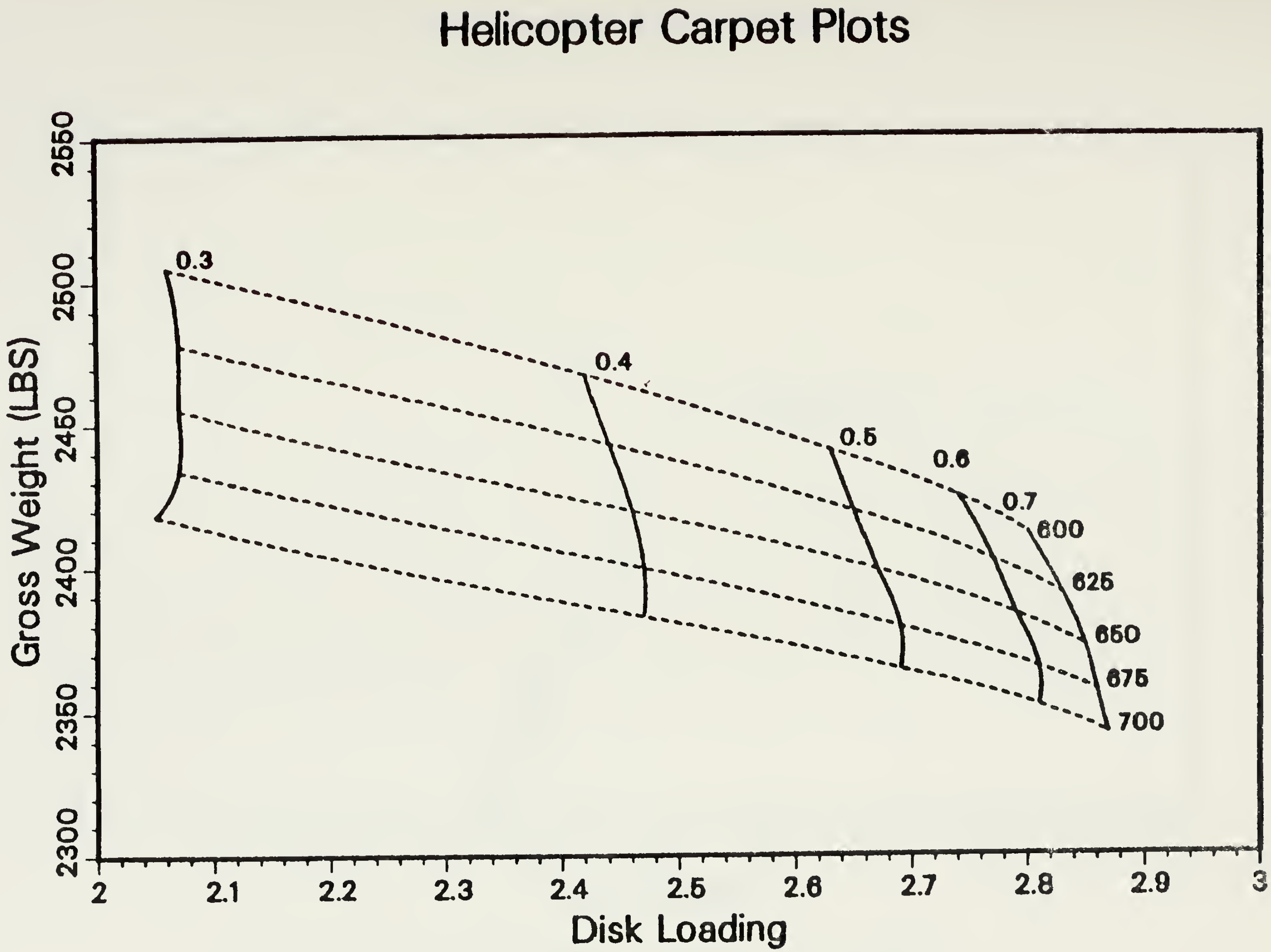

Figure 3.3. Helicopter Carpet Plots
Family of Solutions

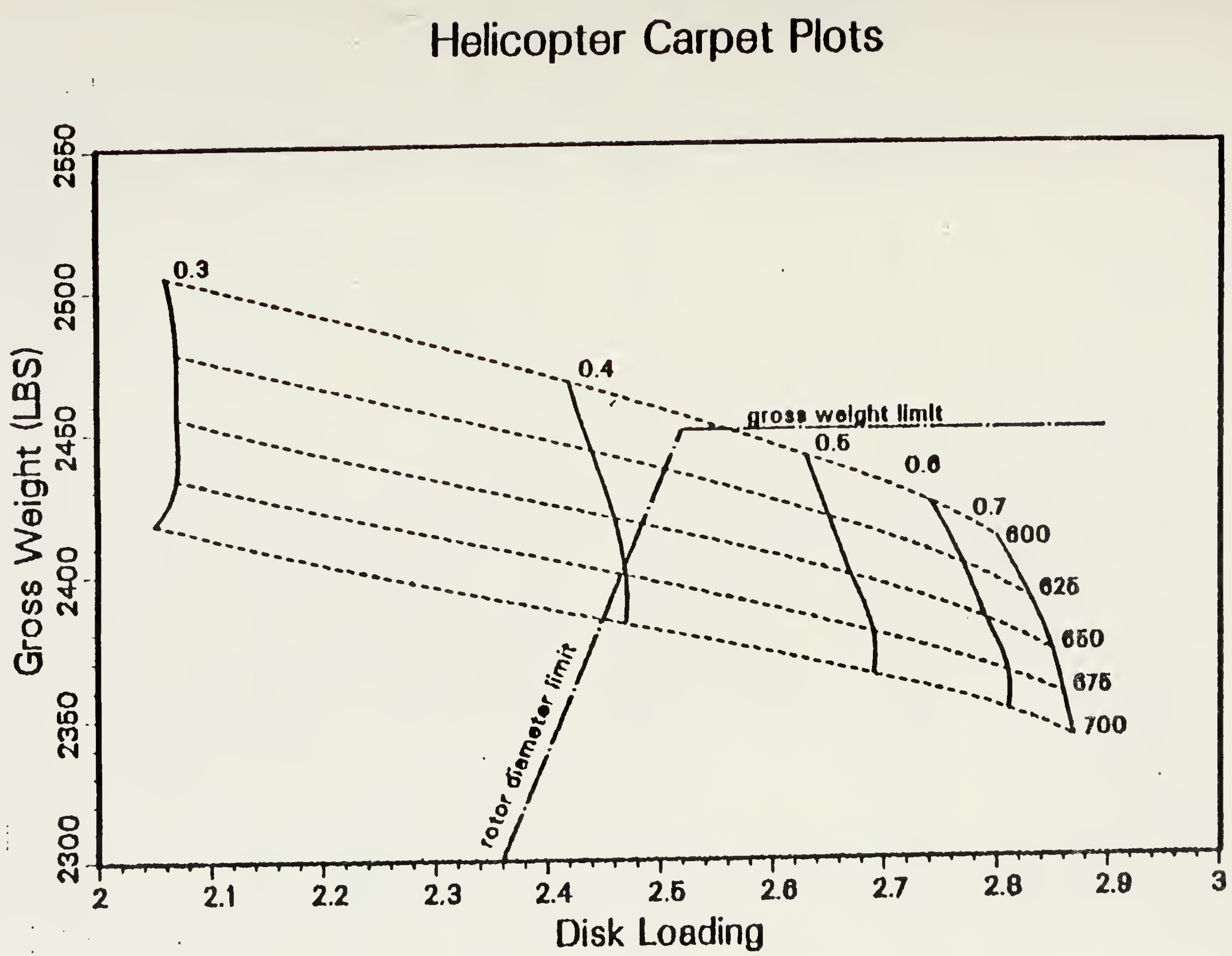

Figure 3.4. Helicopter Carpet Plots Rotor Diameter and Weight Limits

design solutions. Studies have indicated that a main rotor aspect ratio of 21,[1] is a representative upper limit. Thus

$$21 \geq \frac{R<mr>}{C<mr>} = \frac{b}{\pi\sigma} = \frac{b \ \rho_o \ C_{LR} \ V_T^{\ 2}}{\sigma\pi \ DL}$$

or

$$DL \geq \frac{b \ \rho \ C_{LR} \ V_T^{\ 2}}{126\pi}$$

For the case of a two bladed main rotor equation (3.30) reduces to:

$$DL \geq .000012 \ C_{LR} \ V_T^{\ 2}$$

The detemination of this boundary graphically is as follows:

The hover solution plot of Figure 3.2 is replotted[2] relative to the coordinates disk loading and design mean blade lift coefficient. The limiting curves for $DL = .000012 \ C_{LR} \ V_T^{\ 2}$ are then plotted. The intersection with the appropriate constant tip speed lines of the hover solution represent the aspect ratio boundary; Figure 3.5.

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[1]For a helicopter rotor, the aspect ratio is defined as the radius divided by the chord.

[2]For clarity lines of constant gross weight are omitted.

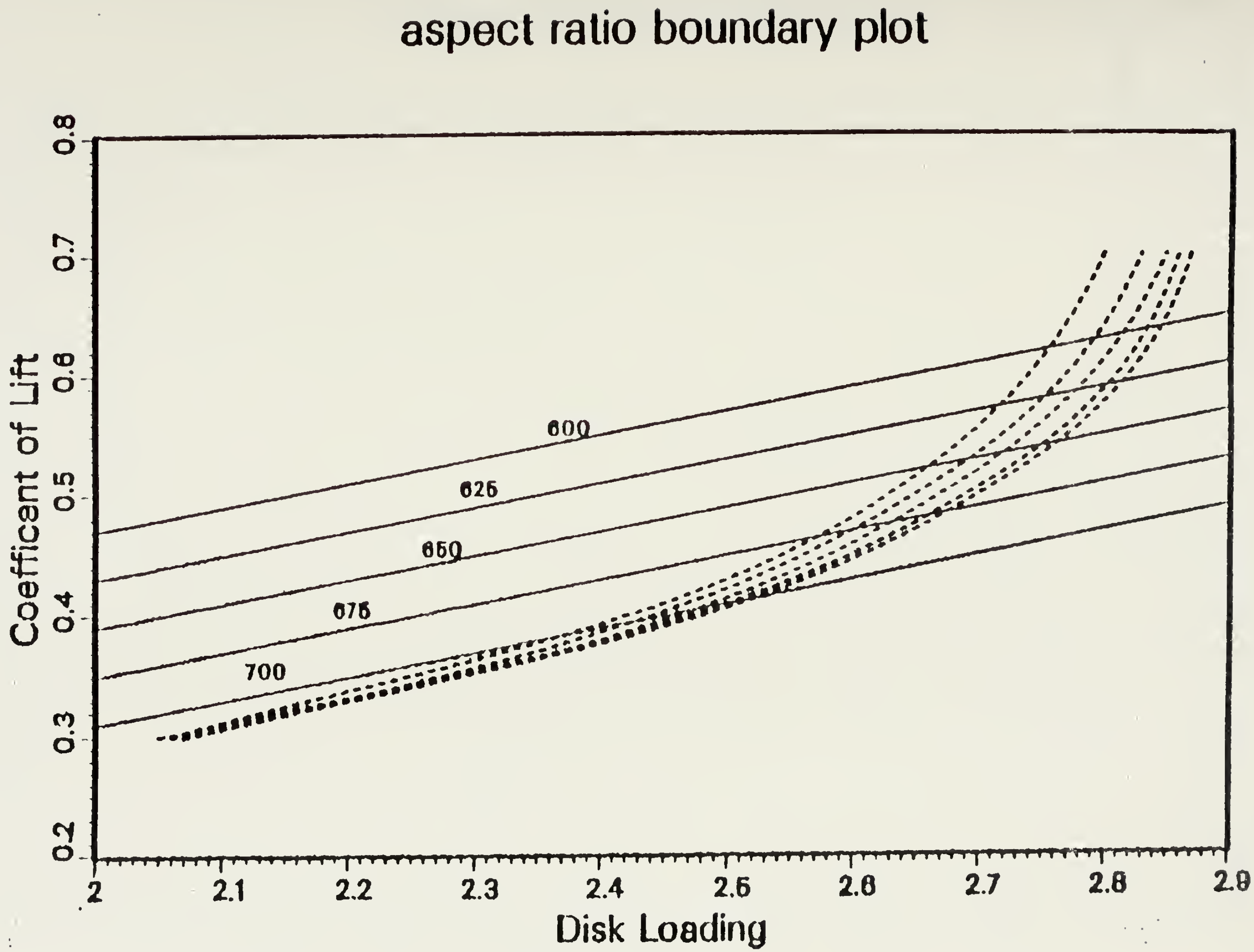


Figure 3.5. Aspect Ratio Boundary Plot

These intersection points are then cross plotted onto Figure 3.4. Figure 3.6 represents a graphical plot of the solution set satisfying the performance and structural design criteria of a small observation helicopter as specified in this study.

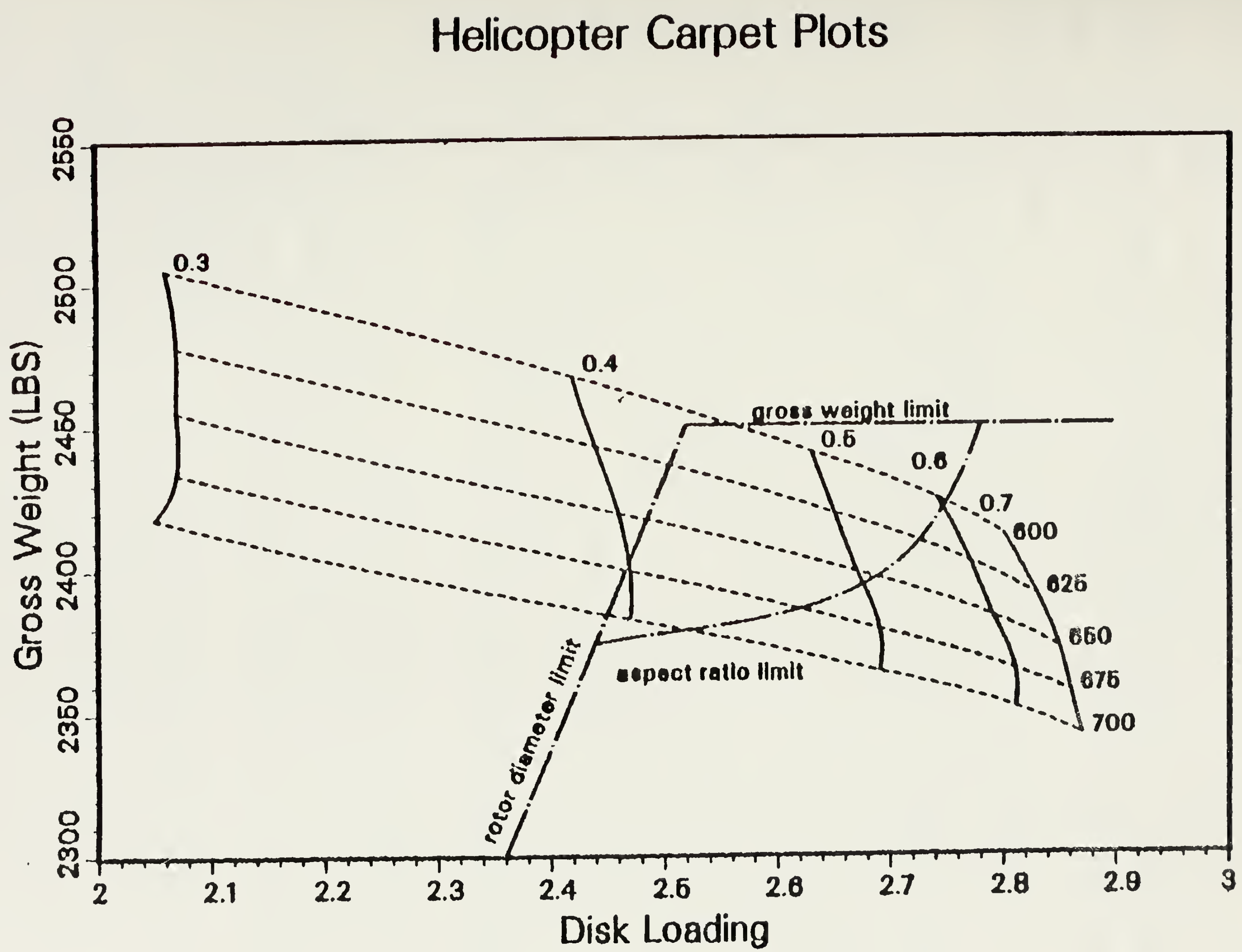


Figure 3.6. Helicopter Carpet Plots
Final Solution

IV. HESCOMP

A. DESCRIPTION OF PROGRAM

HESCOMP is a helicopter sizing and performance computer program developed by the Boeing Vertol Company. The program was originally formulated to provide for rapid configuration design studies.

A number of programming options are available to the user of HESCOMP. When the type and mission profile of the helicopter are known, HESCOMP may be used to size the aircraft. Alternately, it may be used for mission profile calculations when the sizing details [gross weight, payload, engine size, etc.] are specified. A combination of these two options is also available; the program may be used to first size a helicopter for a primary mission and then calculate the off-design performance for other missions. Finally, HESCOMP may be used solely for obtaining helicopter weight.

Sensitivity studies involving both design and performance tradeoffs can easily be done with HESCOMP. Incremental multiplicative and additive factors can be imbedded in the input data.

The various helicopter configurations that may be studied using HESCOMP are detailed in Table 4.1.

TABLE 4.1

HELICOPTER CONFIGURATIONS WHICH MAY BE STUDIED USING HESCOMP

HELICOPTER CONFIGURATIONS WHICH MAY BE STUDIED USING HESCOMP.

Additional Lift/Propulsion System Components Which Must be Added to "Pure" Conf. / Helicopter Type (Both Single & Tandem Rotor)	Wing	Propeller for Auxiliary Propulsion	Auxiliary Independent Engines	Type of Auxiliary Independent Engines		
				T/Shaft	T/Fan	T/Jet
Pure Helicopter						
Winged Helicopter	X					
Compound Helicopter						
(1) Coupled (prim. engines drive auxiliary propulsion system)	X	X				
(2) Auxiliary independent propulsion system						
(a) T/Shaft engine	X	X	X	X		
(b) T/Fan engine	X		X		X	
(c) T/Jet engine	X		X			X
Auxiliary Propulsion Helicopter						
(1) Coupled (prim. engines drive auxiliary propulsion system)		X				
(2) Auxiliary independent propulsion system						
(a) T/Shaft engine		X	X	X		
(b) T/Fan engine			X		X	
(c) T/Jet engine			X			X
Coaxial Rotor Helicopter						
(1) Coupled (prim. engines drive auxiliary propulsion system)		X				
(2) Auxiliary independent propulsion system						
(a) T/Shaft engine		X	X	X		
(b) T/Fan engine			X		X	
(c) T/Jet engine			X			X

B. PROGRAM MODIFICATIONS AND IMPLEMENTATION

The computer program received from Boeing Vertol required some modification and reformating in order to run properly on the Naval Postgraduate School IBM system. These alterations did not, however, alter the program output or usability.

HESCOMP, as received from Boeing Vertol, was 17821 lines long and set-up as a sequential data set to be assemble on a 'G compiler'. The Batch processing system at the Naval Postgraduate School accepts only programs set to run on 'H compiler'. Normally, the differences between these two compilers are minor and programs that run on one will run on the other. However, this was not the case with HESCOMP.

In order to facilitate the program debugging process, HESCOMP was reformatted as a partitioned data set. What this effectively did was to break the program down into eight members of approximately 2000 lines. The program breakdown is illustrated in Table 4.2.

Each of these were compiled individually and then error codes analyzed. The member data set was then modified as required to properly compile.

Once all the members of the partitioned data set compiled properly, HESCOMP was again formated as a sequential data set and run utilizing input data for

which there was a known output. This insured that the modifications made to the original program had not altered the logic, ie., gave faulty results.

The control language program to access HESCOMB on the Batch processing system and a sample input and out data set are shown in Appendix D. These are also available on the Aero disk for copying and use.

TABLE 4.2

PARTITIONED DATA SET

MEMBER NAME	LINE NUMBER	SIZE	FIRST ROUTINE
S1	1 - 1681	1681	AERO
S2	1682 - 4132	2451	CLIMB
S3	4133 - 6531	2399	XIBIV
S4	6532 - 8974	2443	POWAVL
S5	8975 - 10870	1896	PRINT 1
S6	10871 - 13042	2172	ROT POW
S7	13043 - 15383	2341	CRUS 3
S8	15384 - 17821	2448	TAXI

C. PROGRAM FLOW

The program is conceptually outlined in Figure 4.1, [Ref. 7]. The program flow is monitored by a general loop, which controls a series of peripheral programs. There are

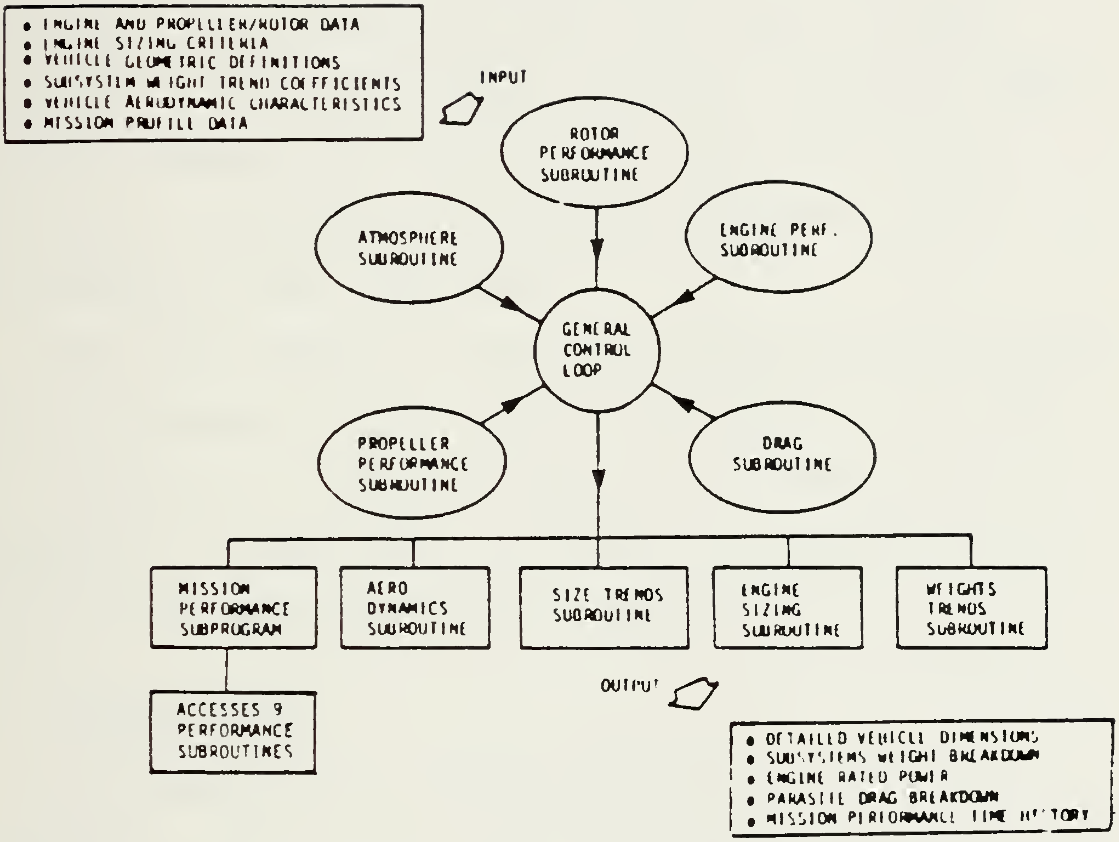


Figure 4.1. HESCOMP Program Flow

a total of 44 subroutines. Detailed program descriptions cam be found in Section 4 of the HESCOMP User's Manual.

D. PROGRAM INPUT

Program input can be loosely group into ten categories: general information, aircraft descriptive information, mission profile information, rotor tip speed schedule, incremental rotor performance, auxiliary propulsion input schedule, engine cycle information, rotor performance information, propeller performance information, and supplementary input information.

The actual amount of input data requires varies greatly with the program options selected. An example of a data set formatted to run on the IBM system is shown in Appendix E. A more detailed explantion is available in Section 5 of the HESCOMP User's Manual.

E. PROGRAM OUTPUT

An example of the program output is included in Appendix E. The printout consists of general data, input data, sizing data [program output] and mission performance data [for the size helicopter]. Detailed descriptions of these and diagnostic error statements are described in Section 6 of Reference 6.

V. CONCLUSIONS AND RECOMMENDATIONS

Three approaches to analyzing a preliminary helicopter design were explored in the course of this paper. It was found that a number of the performance equations could be greatly simplified with little degradation in the final results. A sensitivity analysis brought further insight into the inter-play of the parameters and how changes in them tended to effect the helicopter performance equations.

Carpet Plots provided the most interesting method of analysis. Development of a graphical solution matrix using this method provides a usual interpretation of what is occurring when key parameters are varied.

Two cases were explored; a light observation helicopter in the 3,000 pound weight class and a heavier utility helicopter in the 20,000 pound weight class. The Carpet Plot method provided reasonable solutions in both cases. In doing the analysis for the utility helicopter, the initial weight estimation equation had to be adjusted upward by approximately 2,000 pounds for the equations to intersect properly. This is not considered a limitation to this method of analysis, however, it does point up an area for further investigation. It may be possible to develop more accurate weighing factors for this equation when dealing with higher gross weight helicopters.

HESCOMP provides a plethora of information to the user. However, the price is the amount of inputed data required for even a simplified analysis. At a preliminary design level of analysis, the other methods explored provide a quicker first-cut look at the potential design.

APPENDIX A: NOMENCLATURE

TERM	DEFINITION	UNITS
a	Slope of Airfoil Section Lift Curve	Radians
A	Rotor Disk Area	ft^2
AR	Aspect Ratio	Dimensionless
A_{TR}	Tail Rotor Disk Area	ft^2
b	Number of Rotor Baldes	Dimensionless
B	Tip Loss Factor	Dimensionless
C	Main Rotor Cord	ft
C_{do}	Profile Drag Coefficient at Zero Lift	Dimensionless
C_{LRo}	Design Mean Blade Lift Coefficient at Sea Level	Dimensionless
C_T	Coefficient of Thrust	Dimensionless
C_p	Coefficient of Power	Dimensionless
δ	Blade Section Drag Coefficient	Dimensionless
DL	Disk Loading	lb/ft^2
FM	Figure of Merit	Dimensionless
HP	Horsepower	
L_{TR}	Tail Rotor Moment Arm	ft
ρ	Air Density	$lb\ sec^2/ft^4$
μ	Advance Ratio	Dimensionless
R	Rotor Radius	ft

TERM	DEFINITION	UNITS
P_T	Total Power	HP
P_{TM}	Main Rotor Total Power	HP
P_{TTR}	Tail Rotor Total Power	Hp
P_o	Profile Power	HP
P_i	Induced Power	HP
P_p	Parasite Power	HP
PL	Power Loading	LB/HP
R	Rotor Radius	ft
T	Thrust	HP
V_I	Induced Velocity	ft/sec
V_F	Forward Velocity	ft/sec
V	Aircraft Forward Speed	ft/sec
V_T	Rotor Tip Speed	ft/sec
W	Aircraft Gross Weight	lbs
W_c	Empty Weight	lbs
W_F	Fuel Weight	lbs
W_u	Useful Load	lbs
W_{BAR}	Empty Weight Plust Useful Load	lbs
σ	Solidity	Dimensionless

APPENDIX B: CARPET PLOT FORMULATION FOR 20,000 LB. CLASS HELICOPTER

B1 SPECIFICATIONS:

Maximum Gross Weight: 20,000 pounds
Maximum Rotor Diameter: 30 feet

B2 PRELIMINARY ENGINE SIZING:

B2.1 Utilize equation (2.14) to determine engine horsepower category.

$$W = [4.753P_TR]^{2/3}$$

$$20{,}000 = [47.53P_T\ 30]^{2/3}$$

$$P_T = 1983 \text{ HP}$$

B2.2 Use the engine selection parameters tables B.1 to determine the number and type of power plant [table taken from Reference 3].

B2.2a Type and number selected: 2 type C.

B2.2b Specifications:

Dry Weight Per Engine: 423 pounds

Shaft Horsepower at Standard Sea Level:

Military 1561 HP

Normal 1318 HP

B3 WEIGHT EQUATION FORMULATION

B3.1 To obtain the engine control and accessory weight use items 7, 9, 10, 11, 12 and 13 of the weight estimation relationships developed in Reference 3 for a utility helicopter: #7: 609 lbs; #9: 129 lbs; #10: 76 lbs; #11: 410 lbs; #12: 439 lbs; and #13: 302 lbs.

TABLE B.1

ENGINE SELECTION PARAMETERS

The following turboshat power plant data are presented for one engine.

Engines:		A	B	C	D*	E	F
Dry Weight (lbs)		158	288	423	709	580	750
SHP (ssl)	Military	420	708	1561	1800	2500	3400
	Normal	370	659	1318	1530	2200	3000
	Cruise	278	494	1989	1148	1650	2250
SFC (ssl)	Military	.650	.573	.460	.595	.615	.543
	Normal	.651	.573	.470	.606	.622	.562
	Cruise	.709	.599	.510	.661	.678	.610
Initial Costs		$93K	$100K	$580K	$360K	$640K	$700K
Operating Cost per hour/engine		$8	$16	$20	$35	$40	$60
Preventative Maint per hour/engine		$25	$50	$100	$125	$160	$220
MTBMA (hrs)		3.5	3.0	2.0	3.0	4.0	3.5
MDT (hrs)		0.7	0.6	0.5	1.3	2.0	2.6
MTBF (hrs)		185	210	205	285	280	320
MTBR (hrs)		600	750	800	800	1000	750

B3.2 Simplifications

$$\frac{W}{DL} - A = \pi R^2 \quad , \quad \frac{W}{\ell pm} = MHP = 31,00 \ ; \quad P = \sqrt{\frac{A}{V_T}}$$

B3.3 Engine Group

$$.053(5100)^{1.07} = 272 \text{ lbs}$$

B3.4 Main Transmission

$$10.43 \frac{W^{1.295}}{(\ell pm\ V_t)^{.863} \ [\frac{W}{A}]^{.432}} = 10.43 \frac{W^{.863}\ A^{+.432}}{(\ell pm)^{.863} V_T^{\ .863}}$$

$$= (10.43)(3100)^{.863} P^{.863}$$

$$= 10,748P^{.863}$$

B3.5 Rotor Drive Shaft

$$5.56 \frac{W^{1.05}}{(\ell pm\ V_T)^{.7} \ [\frac{W}{A}]^{.35}} = 5.56(3100)^{.7} P^{.7}$$

$$= 1545P^{.7}$$

B3.6 Tail Rotor

$$32.22 \frac{W^{1.14}}{(\ell pm\ V_T)^{1.14}} = \frac{307,600}{V_T^{\ 1.14}}$$

B3.7 Tail Rotor Gear Box

$$3.7 \frac{W^{.75}}{(\ell pm\ V_T)^{.5}\ [\frac{W}{A}]^{.25}} = (3.7)(3100)^{.5}P^{.5}$$

$$= 206P^{.5}$$

B3.8 Tail Rotor Drive Shaft

$$.124 \frac{W^{1.355}}{(\ell pm)^{.57}\ \frac{W^{.785}}{A^{.785}}} = (.124)(3100)^{.57}P^{.57}\ \sqrt{A}$$

$$= 12.12P^{.57}\ \sqrt{A}$$

B3.9 Landing Gear

$$= .191W^{.916} + .0294W^{.99}$$

B3.10 Rotor Blades Articulated

$$19.77 \frac{W^{1.206}\sigma^{.33}}{V_T\ DL^{.205}}$$

$$= 19.77 \frac{W}{V_T} A^{.205}\sigma^{.33}$$

B3.11 Rotor Hub Articulated

$$.00975 \frac{W^{1.21}}{DL^{.21}} = .00975WA^{.21}$$

B3.12 Fuel System $.0615\ W_F$

Calculation of fuel weight three hours at cruise SHP

1513 lbs + 10%

1664 lbs

B3.13 Total Equation

$$WB = 12{,}987,^{*} + 107948P^{.863} + 1545P^{.7}$$

$$+ \frac{307600}{V_T^{1.14}} + 206P^{.5} + 12.12P^{.57}\sqrt{A}$$

$$+ .191W^{.916} + .0294W^{.99}$$

$$+ 19.77\frac{W}{V_T}A^{.205}S^{.33} + .00975WA^{.21}$$

B4 HOVER EQUATION

Following the formulation in Section of Chapter 3, the weight equation based on the design mean lift coefficient and power required is:

$$W = \frac{K_2\left[1 - 411.51\,\frac{DL^{3/4}}{V_T^{3/2}}\left(1 + K_3\,\frac{V_T}{\sqrt{DL}}\right)^{1/2}\right] - K_4}{V_T + K_5\sqrt{DL}}$$

---

*This number was increased from 8987 to 12987 to bring the curves together. This reflects a 4000 lb useful load.

where:

$$K_1 = \frac{.9583}{C_{LRo}} (1 + 1.8078\ C_{LRo}{}^2)$$

$$K_2 = P_{T6000/950} \frac{(10^5)}{K_1}$$

$$K_3 = \frac{0.00025929}{C_{LR_o}} \ (1 + 1.8078 C_{LRo}{}^2)$$

$$K_4 = \frac{553480.0}{K_1}$$

$$K_5 = \frac{3695.7}{K_1}$$

B.5 GRAPHICAL RESULTS

Figure B.1 is an example of equation (3.13) plotted against equation (B.4) for a specific design mean lift coefficient.

Figure B.2 illustrates the family of curves obtained when the design mean lift coefficient is varied from 0.3 to 0.7 .

In Figure B.3 the solution matrix depicted in Figure B.2 is narrowed by the constraints placed on the gross weight, rotor diameter and aspect ratio.

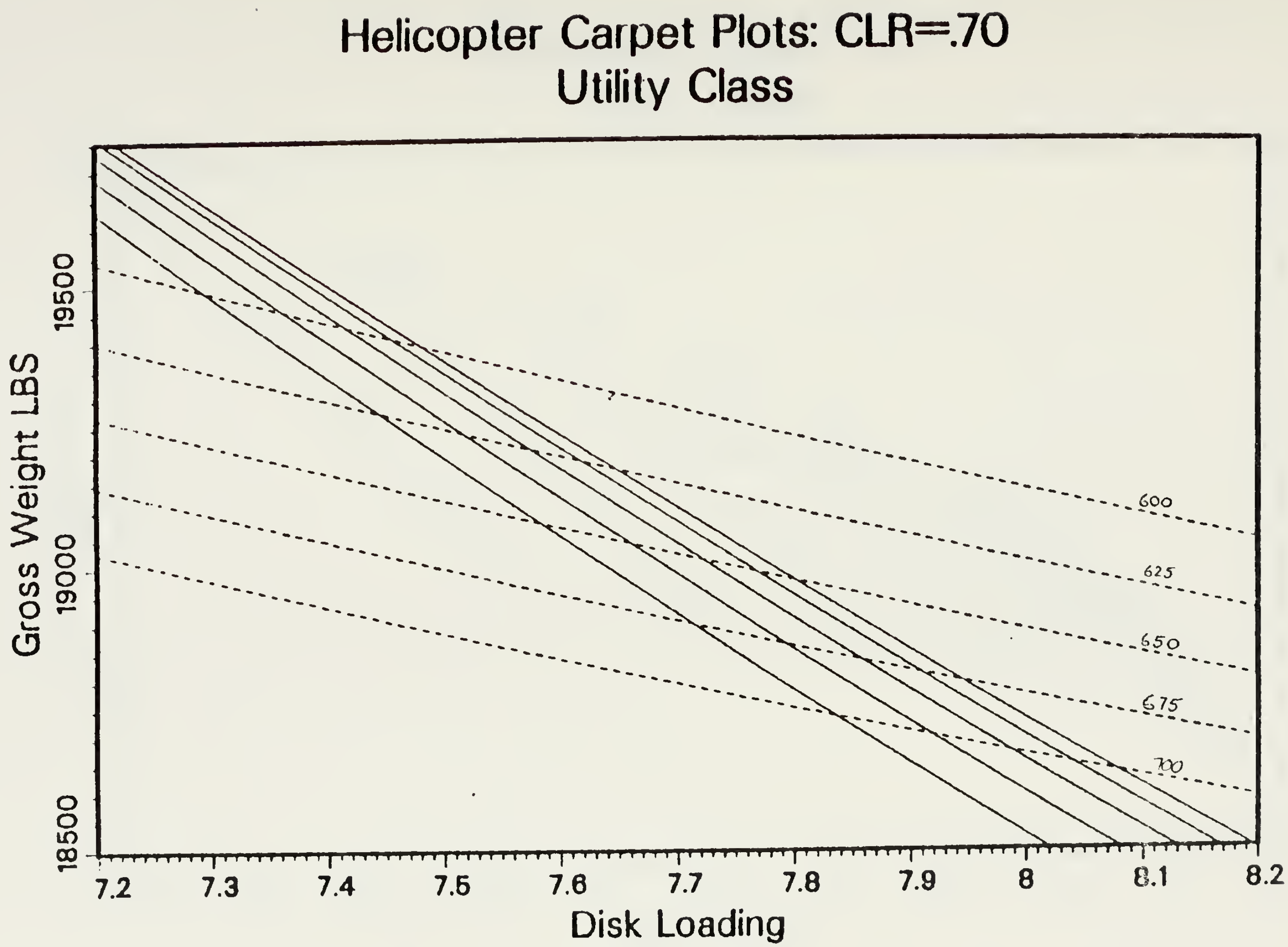


Figure B1. Helicopter Carpet Plots: C_{LR} = .70
Utility Class

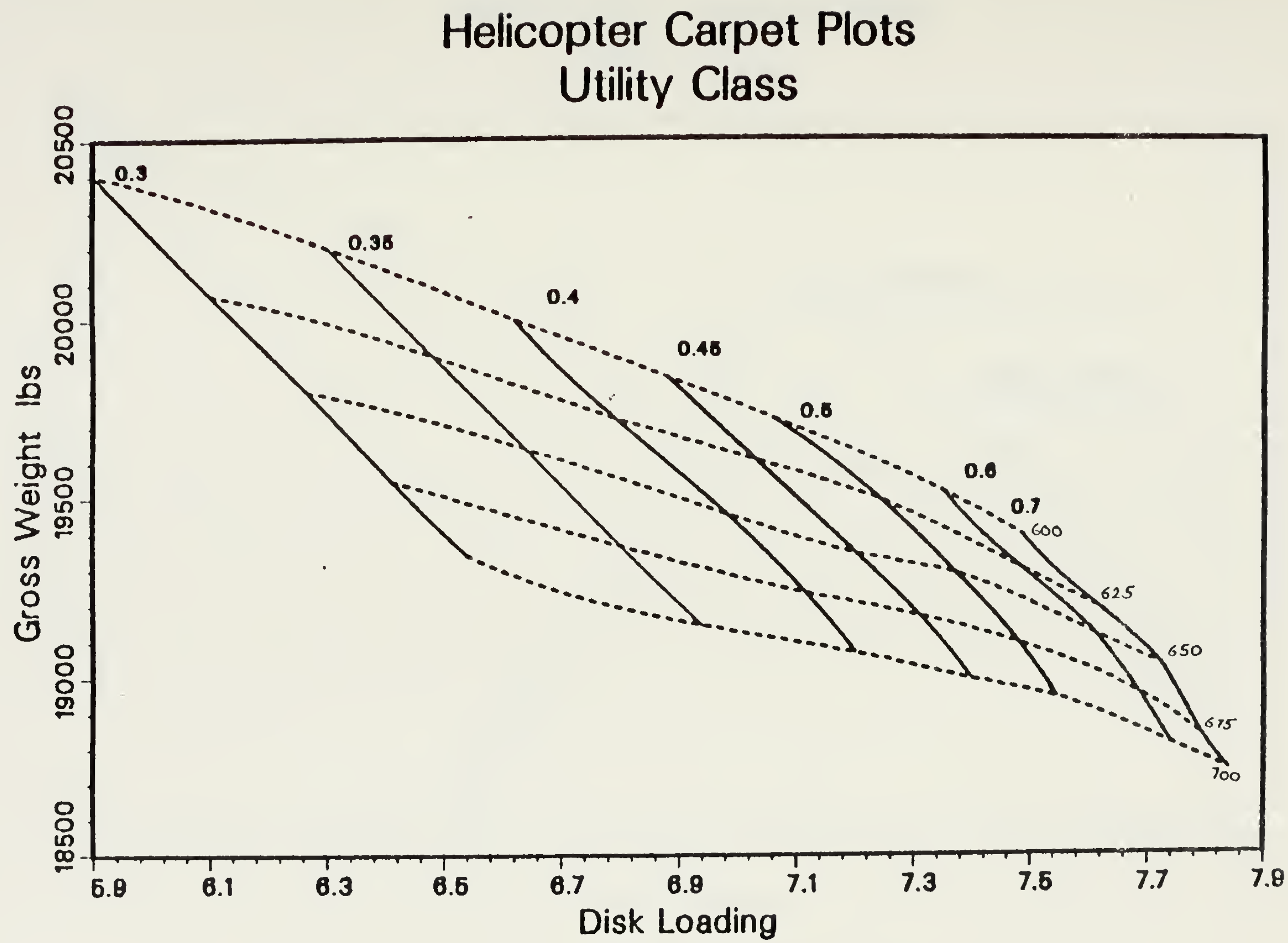


Figure B2. Helicopter Carpet Plots
Utility Class

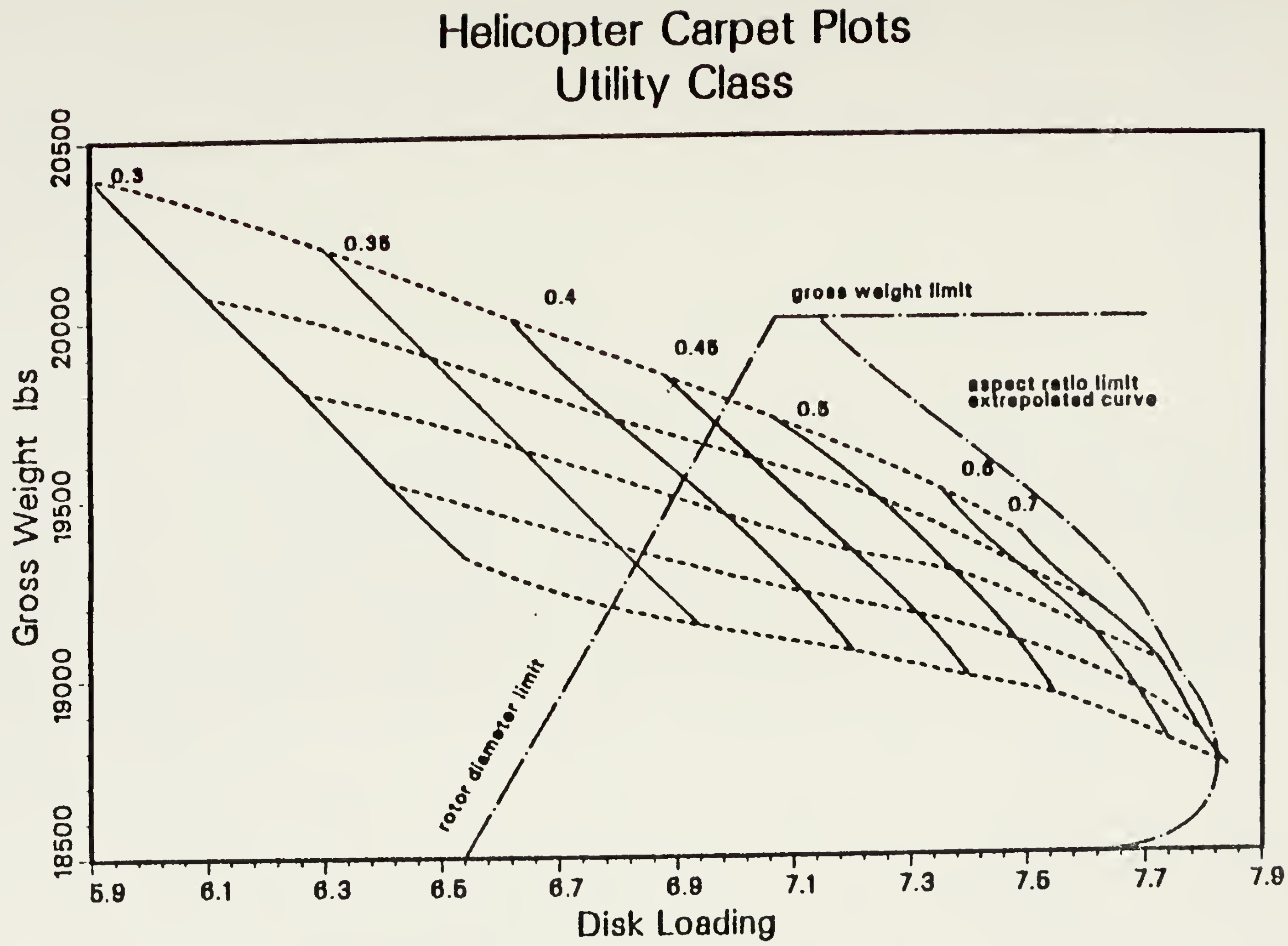
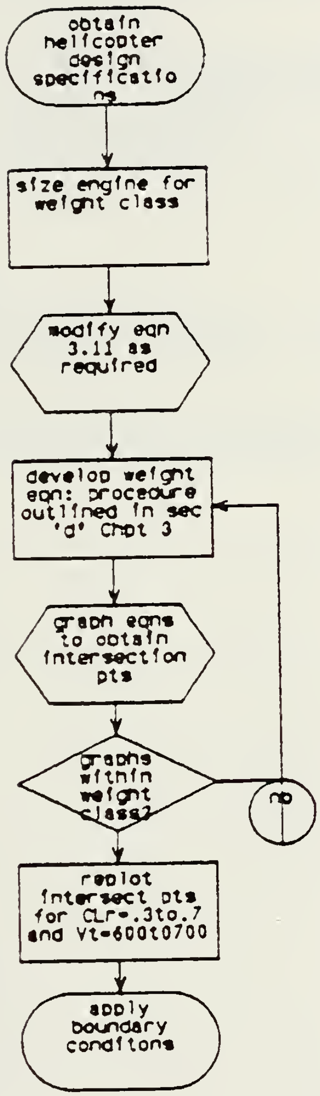


Figure B3. Helicopter Carpet Plots
Utility Class

APPENDIX C. CARPET PLOT METHODOLOGY FLOW CHART AND EXAMPLE PROGRAMS:

This section contains a flow chart to help organize a carpet analysis and example IBM computer programs to produce the data sets and disspla graphs.


obtain helicopter design specifications
size engine for weight class
modify eqn 3.11 as required
develop weight eqn: procedure outlined in sec 'd' Chpt 3
graph eqns to obtain intersection pts
graphs within weight class?
no
replot intersect pts for CLr=.3to.7 and Vt=600to700
apply boundary conditons

```
C*****************************************************************************
C*****************************************************************************
C***********       GRAPHICAL HELICOPTER DESIGN PROGRAM              **********
C*********               CARPET PLOT NUMBER 1                        ********
C*********                BY AL HANSEN                               ********
C*********                                                           ********
C*********     THIS PROGRAM IS DESIGNED TO PROVIDE A WEIGHT VS.      ********
C*********       DISK LOADING GRAPH AT SEVERAL DIFFERENT ROTOR       ********
C*********       TIP VELOCITIES FOR A SPECIFIED DESIGN MEAN          ********
C*********                 LIFT COEFFICENT.                          ********
C***********              OBSERVATION CLASS                         **********
C*****************************************************************************
C*****************************************************************************
C****                                                                    *****
C**                           NOMENCLATURE                                 ***
C*                                                                          **
C*      VARIABLES:                                                          **
C*                                                                          **
C*      CLB      DESIGN MEAN LIFT COEFFICENT                                **
C*      VT       TIP VELOCITY                                               **
C*      DL       DISK LOADING
C*      W        WEIGHT AS CALCULATED FROM POWER EQUATION                   **
C*      WB       USEFUL LOAD PLUS EMPTY WEIGHT                              **
C*      PA       POWER AVAILABLE IN HORSEPOWER                              **
C*                                                                          **
C****                                                                    *****
C*****************************************************************************
      REAL CLR,DL(150),W1(150),W2(150),W3(150),W4(150),W5(150),
     1WB1(150),WB2(150),WB3(150),WB4(150),WB5(150)
C
      INTEGER I
C
C
C---- DEFINE FILES -----------------------------------------------------------
C
      CALL FRTCMS ('FILEDEF ','3        ','DISK    ','CRPT35',
     1            'DATA    ','A        ')
C
C
      CALL FRTCMS ('FILEDEF ','4        ','DISK    ','CRPT45',
     1            'DATA    ','A        ')
C---- READ DATA FROM FILE: CRPTX DATA A -------------------------------
C
      DO 10 I=1,99
C     CRPT1 DATA A
      READ (3,70) DL(I),W1(I),WB1(I),W2(I),WB2(I)
C     CRPT2 DATA A
      READ (4,71) W3(I),WB3(I),W4(I),WB4(I),W5(I),WB5(I)
10    CONTINUE
C
C---- CALL DISSPLA ROUTINES FOR PLOT ----------------------------------
C
      CALL TEK618
      CALL MEDEUF
      CALL RESET (3HALL)
      CALL HWSCAL ('SCREEN')
      CALL PAGE (12.0, 9.5)
      CALL GRACE (0.0)
      CALL PHYSCR (1.0,1.2)
      CALL AREA2D (10.0,6.5)
      CALL FRAME
      CALL SWISSL
      CALL BASALF ('L/CSTD')
      CALL MIXALF ('STAND')
      CALL INTAXS
      CALL YTICKS (5)
      CALL XTICKS (5)
      CALL SHDCHR (-90,1,-015,1)
      CALL HEIGHT (.16)
      CALL XNAME ('(D)ISK (L)OADING$',100)
      CALL YNAME ('(G)ROSS (W)EIGHT ((LBS))$',100)
      CALL HEIGHT (.290)
      CALL HEADIN ('(H)ELICOPTER (C)ARPET (P)LOTS: (CLR=0.5)$',
     1            100,1.0,1)
C     CALL MESSAG ('(H)ELICOPTER (C)ARPET (P)LOTS: (CLR=0.5)$',
C    1            100,3.25,7.55)
```

```
      CALL HEIGHT (.20)
      CALL GRAF (2.3,.1,2.9,2250.,50.,2550.)
      IYGRID=5
      CALL THKCRV (.018)
      CALL LEGLIN
      CALL CURVE (DI,W1,95,0)
      CALL CURVE (DI,W2,95,0)
      CALL CURVE (DI,W3,95,0)
      CALL CURVE (DI,W4,95,0)
      CALL CURVE (DI,W5,95,0)
      CALL DASH
      CALL CURVE (DI,WE1,95,0)
      CALL CURVE (DI,WE2,95,0)
      CALL CURVE (DI,WE3,95,0)
      CALL CURVE (DI,WE4,95,0)
      CALL CURVE (DI,WE5,95,0)
      CALL THKCRV (.030)
C     CALL BLREC (4.2,4.65,1.6,1.35,1)
C     CALL GRID (1,IYGRID)
C     CALL BLOFF (1)
      MAXLIN=LINEST(IPAK1,300,20)
      CALL HEIGHT (.12)
      CALL LINESP (2.0)
      CALL LINES ('(W)EIGHTS$',IPAK1,1)
C     CALL LINES ('(I)NDUCED$',IPAK1,2)
C     CALL LINES ('(P)ROFILES$',IPAK1,3)
C     CALL LINES ('(P)ARASITES$',IPAK1,4)
C     CALL MYLEGN ('(P)OWER (C)URVES',16)
C     CALL LEGEND (IPAK1,4,4.43,4.8)
      CALL DONEPL
      STOP
C     FORMAT STATEMENTS
 70   FORMAT (5(2X,F10.3))
 71   FORMAT (6(2X,F10.3))
      END
```

```
C*****************************************************************************
C*****************************************************************************
C***********      GRAPHICAL HELICOPTER DESIGN PROGRAM                **********
C*********              FAMILY OF SOLUTIONS                           *********
C*********              CARPET PLOT NUMBER 2                           ********
C*********                  BY AL HANSEN                               ********
C*********                                                             ********
C*********    THIS PROGRAM IS DESIGNED TO ILLUSTRATE THE FAMILY       ********
C*********       OF SOLUTIONS FOR HOVER AND USEFUL LOAD               ********
C*********       REQUIREMENTS OF A TEETERING ROTOR SYSTEM              ********
C*********          WITHOUT ANY BOUNDARY CONDITIONS                  ********
C*********                OBSERVATION CLASS                           ********
C***********                                                         **********
C*****************************************************************************
C*****************************************************************************
C****                                                                     *****
C**                             NOMENCLATURE                                ***
C*                                                                           **
C*    VARIABLES:                                                             **
C*                                                                           **
C*    CLR       DESIGN MEAN LIFT COEFFICENT                                  **
C*    VT        TIP VELOCITY                                                 **
C*    DL        DISK LOADING
C*    W         WEIGHT AS CALCULATED FROM POWER EQUATION                     **
C*    WE        USEFUL LOAD PLUS EMPTY WEIGHT                                **
C*    PA        POWER AVAILABLE IN HORSEPOWER                                **
C*                                                                           **
C****                                                                     *****
C*    DL3 EQUALS THE DISK LOADING FOR CLR=.3
C*    DL4 EQUALS THE DISK LOADING FOR CLR=.4
C*    DL5 EQUALS THE DISK LOADING FOR CLR=.5
C*    DL6 EQUALS THE DISK LOADING FOR CLR=.6
C*    DL7 EQUALS THE DISK LOADING FOR CLR=.7
C*    W3 EQUALS THE WEIGHT FOR CLR=.3
C*    W4 EQUALS THE WEIGHT FOR CLR=.4
C*    W5 EQUALS THE WEIGHT FOR CLR=.5
C*    W6 EQUALS THE WEIGHT FOR CLR=.6
C*    W7 EQUALS THE WEIGHT FOR CLR=.7
C*    WVT1 EQUALS WEIGHTS AT VT=600
C*    WVT2 EQUALS WEIGHTS AT VT=625
C*    WVT3 EQUALS WEIGHTS AT VT=650
C*    WVT4 EQUALS WEIGHTS AT VT=675
C*    WVT5 EQUALS WEIGHTS AT VT=700
C*    DVT1 EQUALS THE CORRESPONDING DISK LOADING AT VT=600
C*    DVT2 EQUALS THE CORRESPONDING DISK LOADING AT VT=625
C*    DVT3 EQUALS THE CORRESPONDING DISK LOADING AT VT=650
C*    DVT4 EQUALS THE CORRESPONDING DISK LOADING AT VT=675
C*    DVT5 EQUALS THE CORRESPONDING DISK LOADING AT VT=700
C*****************************************************************************
      REAL*4 DL3(5),DL4(5),DL5(5),DL6(5),DL7(5),W3(5),W4(5),
     *W5(5),W6(5),W7(5),WVT1(5),WVT2(5),WVT3(5),WVT4(5),
     *WVT5(5),DVT1(5),DVT2(5),DVT3(5),DVT4(5),DVT5(5)
C
C---- DEFINE DATA  -----------------------------------------------------------
      DATA DL3/2.06,2.07,2.07,2.07,2.05/
      DATA W3/2505.,2478.2,2455.46,2433.85,2418.25/
      DATA DL4/2.42,2.44,2.46,2.47,2.47/
      DATA W4/2467.17,2442.95,2419.62,2399.72,2382.99/
      DATA DL5/2.63,2.65,2.67,2.69,2.69/
      DATA W5/2440.72,2419.51,2399.00,2379.13,2364.65/
      DATA DL6/2.74,2.77,2.79,2.81,2.81/
      DATA W6/2424.68,2402.48,2383.58,2365.10,2352./
      DATA DL7/2.80,2.83,2.85,2.86,2.87/
      DATA W7/2411.92,2390.72,2372.50,2357.35,2342.25/
      DATA WVT1/2505.,2467.17,2440.72,2424.67,2411.92/
      DATA WVT2/2478.2,2442.95,2419.51,2402.53,2390.72/
      DATA WVT3/2455.46,2419.62,2399.,2383.58,2372.5/
      DATA WVT4/2433.85,2399.72,2379.13,2365.1,2357.35/
      DATA WVT5/2418.25,2382.99,2364.65,2352.,2342.25/
      DATA DVT1/2.06,2.42,2.63,2.74,2.80/
      DATA DVT2/2.07,2.44,2.65,2.77,2.83/
      DATA DVT3/2.07,2.46,2.67,2.79,2.85/
      DATA DVT4/2.07,2.47,2.69,2.81,2.86/
      DATA DVT5/2.05,2.47,2.69,2.81,2.87/
C
C
```

```
C---- CALL DISSPLA ROUTINES FOR PLOT -----------------------------------
C
      CALL TEK618
      CALL MEDEUF
      CALL RESET (3HALL)
      CALL HWSCAL ('SCREEN')
      CALL PAGE (12.0, 9.5)
      CALL GRACE (0.0)
      CALL PHYSCR (1.0,1.2)
      CALL AREA2D (10.0,6.5)
      CALL FRAME
      CALL SWISSL
      CALL BASALF ('L/CSTD')
      CALL MIXALF ('STAND')
      CALL INTAXS
      CALL YTICKS (5)
      CALL XTICKS (5)
      CALL SHDCHR (.90,1,.015,1)
      CALL HEIGHT (.16)
      CALL XNAME ('(D)ISK (L)OADING$',100)
      CALL YNAME ('(G)ROSS (W)EIGHT ((LBS))$',100)
      CALL HEIGHT (.290)
      CALL HEADIN ('(H)ELICOPTER (C)ARPET (P)LOTS$',
     1            100,1.0,1)
      CALL HEIGHT (.20)
      CALL GRAF (2.0,.1,3.0,2300.,50.,2550.)
      IYGRID=5
      CALL THKCRV (.018)
      CALL PARA3
      CALL LEGLIN
      CALL CURVE (DL3,W3,5,0)
      CALL CURVE (DL4,W4,5,0)
      CALL CURVE (DL5,W5,5,0)
      CALL CURVE (DL6,W6,5,0)
      CALL CURVE (DL7,W7,5,0)
      CALL DASH
      CALL CURVE (DVT1,WVT1,5,0)
      CALL CURVE (DVT2,WVT2,5,0)
      CALL CURVE (DVT3,WVT3,5,0)
      CALL CURVE (DVT4,WVT4,5,0)
      CALL CURVE (DVT5,WVT5,5,0)
      CALL THKCRV (.030)
C     CALL BLREC (4.2,4.65,1.6,1.35,1)
C     CALL GRID (1,IYGRID)
C     CALL BLOFF (1)
C     MAXLIN=LINEST(IPAK1,300,20)
C     CALL HEIGHT (.12)
C     CALL LINESP (2.0)
C     CALL LINES ('(W)EIGHTS$',IPAK1,1)
C     CALL LINES ('(I)NDUCED$',IPAK1,2)
C     CALL LINES ('(P)ROFILES$',IPAK1,3)
C     CALL LINES ('(P)ARASITES$',IPAK1,4)
C     CALL MYLEGN ('(P)OWER (C)URVES',16)
C     CALL LEGEND (IPAK1,4,4.43,4.8)
      CALL DONEPL
      STOP
C     FORMAT STATEMENTS
C70   FORMAT (5(2X,F10.3))
C71   FORMAT (6(2X,F10.3))
      END
```

```
C************************************************************************
C************************************************************************
C**********      GRAPHICAL HELICOPTER DESIGN PROGRAM            **********
C*********          ASPECT RATIO BOUNDARY                        *********
C********        LOCI OF HOVER AND USEFUL-LOAD SOLUTIONS          ********
C********              CARPET PLOT NUMBER 3                       ********
C********                 BY AL HANSEN                            ********
C********                                                         ********
C********     THIS PROGRAM IS DESIGNED TO GRAPHICALLY DETERMINE   ********
C********       THE ASPECT RATIO BOUNDARY REQUIREMENTS FOR        ********
C********       A ROTOR SYSTEM USING PREVIOUSLY GENERATED DATA    ********
C**********                                                     **********
C************************************************************************
C************************************************************************
C****                                                                ****
C**                            NOMENCLATURE                            **
C*                                                                     **
C*     VARIABLES:                                                      **
C*                                                                     **
C*     CLB       DESIGN MEAN LIFT COEFFICENT                           **
C*     VT        TIP VELOCITY                                          **
C*     DL        DISK LOADING                                          **
C*     AR        ASPECT RATIO. HISTORICALLLY ASSUMED TO BE LESS THAN 21 **
C*                                                                     **
C****                                                                ****
C*     DVT1 EQUALS THE CORRESPONDING DISK LOADING AT VT=600
C*     DVT2 EQUALS THE CORRESPONDING DISK LOADING AT VT=625
C*     DVT3 EQUALS THE CORRESPONDING DISK LOADING AT VT=650
C*     DVT4 EQUALS THE CORRESPONDING DISK LOADING AT VT=675
C*     DVT5 EQUALS THE CORRESPONDING DISK LOADING AT VT=700
C*     C600 EQUALS THE LIFT COEF AT VT=600
C*     C625 EQUALS THE LIFT COEF AT VT=625
C*     C650 EQUALS THE LIFT COEF AT VT=650
C*     C675 EQUALS THE LIFT COEF AT VT=675
C*     C700 EQUALS THE LIFT COEF AT VT=700
C************************************************************************
      REAL*4  CLR(5),DL(10),C600(10),C625(10),C650(10),
     *C675(10),C700(10),
     *DVT1(5),DVT2(5),DVT3(5),DVT4(5),DVT5(5)
C
C---- DEFINE DATA  -------------------------------------------------------
      DATA DVT1/2.06,2.42,2.63,2.74,2.80/
      DATA DVT2/2.07,2.44,2.65,2.77,2.83/
      DATA DVT3/2.07,2.46,2.67,2.79,2.85/
      DATA DVT4/2.07,2.47,2.69,2.81,2.86/
      DATA DVT5/2.05,2.48,2.70,2.82,2.87/
      DATA CLR/.3,.4,.5,.6,.7/
      DATA DL/2.,2.1,2.2,2.3,2.4,2.5,2.6,2.7,2.8,2.9/
      DATA C600/.47,.49,.51,.53,.55,.57,.59,.61,.63,.65/
      DATA C625/.43,.45,.47,.49,.51,.53,.55,.57,.59,.61/
      DATA C650/.39,.41,.43,.45,.47,.49,.51,.53,.55,.57/
      DATA C675/.35,.37,.39,.41,.43,.45,.47,.49,.51,.53/
      DATA C700/.31,.33,.35,.37,.39,.41,.43,.45,.47,.49/
C
C
C---- CALL DISSPLA ROUTINES FOR PLOT ------------------------------------
C
      CALL TEK618
      CALL MEDEUF
      CALL RESET (3HALL)
      CALL HWSCAL ('SCREEN')
      CALL PAGE (12.0, 9.5)
      CALL GRACE (0.0)
      CALL PHYSOR (1.0,1.2)
      CALL AREA2D (10.0,6.5)
      CALL FRAME
      CALL SWISSL
      CALL BASALF ('L/CSTD')
      CALL MIXALF ('STAND')
      CALL INTAXS
      CALL SHDCHR (.90,1,.015,1)
      CALL HEIGHT (.16)
      CALL XNAME ('(D)ISK (L)OADING$',100)
      CALL YNAME ('(C)OEFFICENT OF (L)IFT$',100)
      CALL HEIGHT (.290)
      CALL MESSAG ('(H)ELICOPTER (C)ARPET (P)LOTS$',
```

```
1                  1C0.3.25,7.55)
 CALL HEIGHT (.20)
 CALL GRAF (2.0,.1,2.9,.2,.05,.8)
 IYGRID=5
 CALL THKCRV (.C16)
 CALL PARA3
 CALL LEGLIN
 CALL CURVE (DI,C6CC,10,0)
 CALL CURVE (DI,C625,10,0)
 CALL CURVE (DI,C650,10,0)
 CALL CURVE (DI,C675,10,0)
 CALL CURVE (DI,C7CC,10,0)
 CALL DASH
 CALL CURVE (DVT1,CIR,5,0)
 CALL CURVE (DVT2,CIR,5,0)
 CALL CURVE (DVT3,CIR,5,0)
 CALL CURVE (DVT4,CIR,5,0)
 CALL CURVE (DVT5,CIR,5,0)
 CALL THKCRV (.C30)
 CALL DONEPL
 STOP
 END
```

```
C*****************************************************************
C*****************************************************************
C**********      GRAPHICAL HELICOPTER DESIGN PROGRAM      **********
C********               FAMILY OF SOLUTIONS                ********
C********              CARPET PLOT NUMBER 4                ********
C********                 BY AL HANSEN                     ********
C********                                                  ********
C********  THIS PROGRAM IS DESIGNED TO ILLUSTRATE THE FAMILY ********
C********   OF SOLUTIONS FOR HOVER AND USEFUL LOAD         ********
C********   REQUIREMENTS OF A TEETERING ROTOR SYSTEM       ********
C********   WITH ROTOR DIAMETER AND MAX GROSS BOUNDRIES.   ********
C********          OBSERVATION CLASS HELICOPTER            ********
C**********                                               **********
C*****************************************************************
C*****************************************************************
C****                                                          *****
C**                        NOMENCLATURE                          ***
C*                                                                **
C*     VARIABLES:                                                 **
C*                                                                **
C*     CLR      DESIGN MEAN LIFT COEFFICENT                       **
C*     VT       TIP VELOCITY                                      **
C*     DL       DISK LOADING
C*     W        WEIGHT AS CALCULATED FROM POWER EQUATION          **
C*     WB       USEFUL LOAD PLUS EMPTY WEIGHT                     **
C*     PA       POWER AVAILABLE IN HORSEPOWER                     **
C*                                                                **
C****                                                           *****
C*     DL3 EQUALS THE DISK LOADING FOR CLR=.3
C*     DL4 EQUALS THE DISK LOADING FOR CLR=.4
C*     DL5 EQUALS THE DISK LOADING FOR CLR=.5
C*     DL6 EQUALS THE DISK LOADING FOR CLR=.6
C*     DL7 EQUALS THE DISK LOADING FOR CLR=.7
C*     W3 EQUALS THE WEIGHT FOR CLR=.3
C*     W4 EQUALS THE WEIGHT FOR CLR=.4
C*     W5 EQUALS THE WEIGHT FOR CLR=.5
C*     W6 EQUALS THE WEIGHT FOR CLR=.6
C*     W7 EQUALS THE WEIGHT FOR CLR=.7
C*     WVT1 EQUALS WEIGHTS AT VT=600
C*     WVT2 EQUALS WEIGHTS AT VT=625
C*     WVT3 EQUALS WEIGHTS AT VT=650
C*     WVT4 EQUALS WEIGHTS AT VT=675
C*     WVT5 EQUALS WEIGHTS AT VT=700
C*     DVT1 EQUALS THE CORRESPONDING DISK LOADING AT VT=600
C*     DVT2 EQUALS THE CORRESPONDING DISK LOADING AT VT=625
C*     DVT3 EQUALS THE CORRESPONDING DISK LOADING AT VT=650
C*     DVT4 EQUALS THE CORRESPONDING DISK LOADING AT VT=675
C*     DVT5 EQUALS THE CORRESPONDING DISK LOADING AT VT=700
C*     RDB ROTOR DISK BOUNDARY
C*     WMG MAX GROSS WEIGHT BOUNDARY
C*****************************************************************
      REAL*4 DL3(5),DL4(5),DL5(5),DL6(5),DL7(5),W3(5),W4(5),RDB(2),
     *W5(5),W6(5),W7(5),WVT1(5),WVT2(5),WVT3(5),WVT4(5),WMG(2),
     *WVT5(5),DVT1(5),DVT2(5),DVT3(5),DVT4(5),DVT5(5),D1(2),D2(2)
C
C---- DEFINE DATA  ------------------------------------------------
      DATA DL3/2.06,2.07,2.07,2.07,2.05/
      DATA W3/2505.,2478.2,2455.46,2433.85,2418.25/
      DATA DL4/2.42,2.44,2.46,2.47,2.47/
      DATA W4/2467.17,2442.95,2419.62,2399.72,2382.99/
      DATA DL5/2.63,2.65,2.67,2.69,2.69/
      DATA W5/2440.72,2419.51,2399.00,2379.13,2364.65/
      DATA DL6/2.74,2.77,2.79,2.81,2.81/
      DATA W6/2424.68,2402.48,2383.58,2365.10,2352./
      DATA DL7/2.80,2.83,2.85,2.86,2.87/
      DATA W7/2411.92,2390.72,2372.50,2357.35,2342.25/
      DATA WVT1/2505.,2467.17,2440.72,2424.67,2411.92/
      DATA WVT2/2478.2,2442.95,2419.51,2402.53,2390.72/
      DATA WVT3/2455.46,2419.62,2399.,2383.58,2372.5/
      DATA WVT4/2433.85,2399.72,2379.13,2365.1,2357.35/
      DATA WVT5/2418.25,2382.99,2364.65,2352.,2342.25/
      DATA DVT1/2.06,2.42,2.63,2.74,2.80/
      DATA DVT2/2.07,2.44,2.65,2.77,2.83/
      DATA DVT3/2.07,2.46,2.67,2.79,2.85/
      DATA DVT4/2.07,2.47,2.69,2.81,2.86/
      DATA DVT5/2.05,2.47,2.69,2.81,2.87/
```

```
      DATA D1/2.52,2.9/
      DATA WMG/2450.,2450./
      DATA D2/2.36,2.52/
      DATA RDB/2300.,2450./
C
C
C---- CALL DISSPLA ROUTINES FOR PLOT ------------------------------------
C
      CALL TEK618
      CALL MEDBUF
      CALL RESET (3HALL)
      CALL HWSCAL ('SCREEN')
      CALL PAGE (12.C, 9.5)
      CALL GRACE (0.0)
      CALL PHYSCR (1.0,1.2)
      CALL AREA2D (10.,6.5)
      CALL FRAME
      CALL SWISSL
      CALL BASALF ('L/CSTD')
      CALL MIXALF ('STAND')
      CALL INTAXS
      CALL YTICKS (5)
      CALL XTICKS (5)
      CALL SHDCHR (.90,1,.015,1)
      CALL HEIGHT (.16)
      CALL XNAME ('(D)ISK (L)OADING$',100)
      CALL YNAME ('(G)ROSS (W)EIGHT ((LBS))$',100)
      CALL HEIGHT (.290)
      CALL HEADIN ('(H)ELICOPTER (C)ARPET (P)LOTS$',
     1            100,1.0,1)
      CALL HEIGHT (.20)
      CALL GRAF (2.0,.1,3.0,2300.,50.,2550.)
      IYGRID=5
      CALL THKCRV (.018)
      CALL PARA3
      CALL LEGLIN
      CALL CURVE (DL3,W3,5,0)
      CALL CURVE (DL4,W4,5,0)
      CALL CURVE (DL5,W5,5,0)
      CALL CURVE (DL6,W6,5,0)
      CALL CURVE (DL7,W7,5,0)
      CALL DASH
      CALL CURVE (DVT1,WVT1,5,0)
      CALL CURVE (DVT2,WVT2,5,0)
      CALL CURVE (DVT3,WVT3,5,0)
      CALL CURVE (DVT4,WVT4,5,0)
      CALL CURVE (DVT5,WVT5,5,0)
      CALL THKCRV (.030)
      CALL CHNDOT
      CALL CURVE (D1,WMG,2,0)
      CALL CURVE (D2,RDB,2,0)
      CALL DONEPL
      STOP
      END
```

```
C*************************************************************************
C*************************************************************************
C**********       GRAPHICAL HELICOPTER DESIGN PROGRAM              **********
C*********              FAMILY OF SOLUTIONS                         *********
C*********              CARPET PLOT NUMBER 5                        *********
C*********                BY AL HANSEN                              *********
C*********                                                          *********
C*********     THIS PROGRAM IS DESIGNED TO ILLUSTRATE THE FAMILY    *********
C*********        OF SOLUTIONS FOR HOVER AND USEFUL LOAD            *********
C*********        REQUIREMENTS OF A TEETERING ROTOR SYSTEM          *********
C*********        WITH ROTOR DIAMETER, MAX GROSS WEIGHT AND         *********
C*********              ASPECT RATIO BOUNDARIES.                    *********
C*********              OBSERVATION CLASS HELICOPTER                *********
C***********                                                      ***********
C*************************************************************************
C*************************************************************************
C****                                                                 *****
C**                           NOMENCLATURE                              ***
C*                                                                       **
C*     VARIABLES:                                                        **
C*                                                                       **
C*     CLR       DESIGN MEAN LIFT COEFFICENT                             **
C*     VT        TIP VELOCITY                                            **
C*     DL        DISK LOADING                                            
C*     W         WEIGHT AS CALCULATED FROM POWER EQUATION                **
C*     WE        USEFUL LOAD PLUS EMPTY WEIGHT                           **
C*     PA        POWER AVAILABLE IN HORSEPOWER                           **
C*                                                                       **
C****                                                                 *****
C*     DL3 EQUALS THE DISK LOADING FOR CLR=.3
C*     DL4 EQUALS THE DISK LOADING FOR CLR=.4
C*     DL5 EQUALS THE DISK LOADING FOR CLR=.5
C*     DL6 EQUALS THE DISK LOADING FOR CLR=.6
C*     DL7 EQUALS THE DISK LOADING FOR CLR=.7
C*     W3 EQUALS THE WEIGHT FOR CLR=.3
C*     W4 EQUALS THE WEIGHT FOR CLR=.4
C*     W5 EQUALS THE WEIGHT FOR CLR=.5
C*     W6 EQUALS THE WEIGHT FOR CLR=.6
C*     W7 EQUALS THE WEIGHT FOR CLR=.7
C*     WVT1 EQUALS WEIGHTS AT VT=600
C*     WVT2 EQUALS WEIGHTS AT VT=625
C*     WVT3 EQUALS WEIGHTS AT VT=650
C*     WVT4 EQUALS WEIGHTS AT VT=675
C*     WVT5 EQUALS WEIGHTS AT VT=700
C*     DVT1 EQUALS THE CORRESPONDING DISK LOADING AT VT=600
C*     DVT2 EQUALS THE CORRESPONDING DISK LOADING AT VT=625
C*     DVT3 EQUALS THE CORRESPONDING DISK LOADING AT VT=650
C*     DVT4 EQUALS THE CORRESPONDING DISK LOADING AT VT=675
C*     DVT5 EQUALS THE CORRESPONDING DISK LOADING AT VT=700
C*     RDB ROTOR DISK BOUNDARY
C*     WMG MAX GROSS WEIGHT BOUNDARY
C*     AR WEIGHTS FOR THE ASPECT RATIO BOUNDARY
C*     D3 DISK LOADING CORRESPONDING TO THE ASPECT RATIO WEIGHTS
C**************************************************************************
      REAL*4 DL3(5),DL4(5),DL5(5),DL6(5),DL7(5),W3(5),W4(5),RDB(2),
     *W5(5),W6(5),W7(5),WVT1(5),WVT2(5),WVT3(5),WVT4(5),WMG(2),
     *WVT5(5),DVT1(5),DVT2(5),DVT3(5),DVT4(5),DVT5(5),D1(2),D2(2),
     *D3(5),AR(5)
C
C---- DEFINE DATA ---------------------------------------------------------
      DATA DL3/2.06,2.07,2.07,2.07,2.05/
      DATA W3/2505.,2478.2,2455.46,2433.85,2418.25/
      DATA DL4/2.42,2.44,2.46,2.47,2.47/
      DATA W4/2467.17,2442.95,2419.62,2399.72,2382.99/
      DATA DL5/2.63,2.65,2.67,2.69,2.69/
      DATA W5/2440.72,2419.51,2399.00,2379.13,2364.65/
      DATA DL6/2.74,2.77,2.79,2.81,2.81/
      DATA W6/2424.68,2402.48,2383.58,2365.10,2352./
      DATA DL7/2.80,2.83,2.85,2.86,2.87/
      DATA W7/2411.92,2390.72,2372.50,2357.35,2342.25/
      DATA WVT1/2505.,2467.17,2440.72,2424.67,2411.92/
      DATA WVT2/2478.2,2442.95,2419.51,2402.53,2390.72/
      DATA WVT3/2455.46,2419.62,2399.,2383.58,2372.5/
      DATA WVT4/2433.85,2399.72,2379.13,2365.1,2357.35/
      DATA WVT5/2418.25,2382.99,2364.65,2352.,2342.25/
      DATA DVT1/2.06,2.42,2.63,2.74,2.80/
```

```
      DATA DVT2/2.07,2.44,2.65,2.77,2.83/
      DATA DVT3/2.07,2.46,2.67,2.79,2.85/
      DATA DVT4/2.07,2.47,2.69,2.81,2.86/
      DATA DVT5/2.05,2.47,2.69,2.81,2.87/
      DATA D1/2.52,2.9/
      DATA WMG/2450.,2450./
      DATA D2/2.36,2.52/
      DATA RDB/2300.,2450./
      DATA AR/2374.461,2390.,2405.,2420.,2450./
      DATA D3/2.44,2.65,2.715,2.745,2.78/
C
C
C---- CALL DISSPLA ROUTINES FOR PLOT -----------------------------------
C
      CALL TEK618
      CALL MEDEUF
      CALL RESET (3HALL)
      CALL HWSCAL ('SCREEN')
      CALL PAGE (12.0, 9.5)
      CALL GRACE (0.0)
      CALL PHYSOR (1.0,1.2)
      CALL AREA2D (10.,6.5)
      CALL FRAME
      CALL SWISSL
      CALL BASALF ('L/CSTD')
      CALL MIXALF ('STAND')
      CALL INTAXS
      CALL YTICKS (5)
      CALL XTICKS (5)
      CALL SHDCHR (.90,1,.015,1)
      CALL HEIGHT (.16)
      CALL XNAME ('(D)ISK (L)OADING$',100)
      CALL YNAME ('(G)ROSS (W)EIGHT ((LBS))$',100)
      CALL HEIGHT (.290)
      CALL HEADIN ('(H)ELICOPTER (C)ARPET (P)LOTS$',
     1             100,1.0,1)
      CALL HEIGHT (.20)
      CALL GRAF (2.0,.1,3.0,2300.,50.,2550.)
      IYGRID=5
      CALL THKCRV (.018)
      CALL PARA3
      CALL LEGLIN
      CALL CURVE (DL3,W3,5,0)
      CALL CURVE (DL4,W4,5,0)
      CALL CURVE (DL5,W5,5,0)
      CALL CURVE (DL6,W6,5,0)
      CALL CURVE (DL7,W7,5,0)
      CALL DASH
      CALL CURVE (DVT1,WVT1,5,0)
      CALL CURVE (DVT2,WVT2,5,0)
      CALL CURVE (DVT3,WVT3,5,0)
      CALL CURVE (DVT4,WVT4,5,0)
      CALL CURVE (DVT5,WVT5,5,0)
      CALL THKCRV (.030)
      CALL CHNDOT
      CALL CURVE (D1,WMG,2,0)
      CALL CURVE (D2,RDB,2,0)
      CALL CURVE (D3,AR,5,0)
      CALL DONEPL
      STOP
      END
```

```
C   THIS PROGRAM IS DESIGN TO GENERATE THE DATA FOR THE GRAPHICAL
C   SOLUTION OF THE WEIGHT AND THE USEFUL LOAD EQUATION.  THIS IS THE
C   FIRST STEP IN A CARPET PLOT HELICOPTER DESIGN PARAMETRIC OPTIMIZATION
C
C       ASSUMPTIONS:
C                     1> ENGINESPECIFIED
C  VARIABLE OPTIONS
C
        REAL*4 CLB,PA,DL,K1,K2,K3,K4,K5,R,S,A,P,W(10),WB(10)
        INTEGER VT,D,I,CL
C
C-----------------------------------------------------------------------
        CALL FRTCMS ('FILEDEF ','02        ','DISK    ','CRPT1',
      >'DATA    ','A        ')
C-----------------------------------------------------------------------
C-----------------------------------------------------------------------
        CALL FRTCMS ('FILEDEF ','03        ','DISK    ','CRPT2',
      >'DATA    ','A        ')
C-----------------------------------------------------------------------
C
C       CLB= DESIGN MEAN LIFT COEFFICIENT
        DO 90 CL=3,7
        CLB=CL*(0.1)
        WRITE(2,10)CLB
C       PA= POWER AVAILABLE HP
        PA=206
C       DL= DISK LOADING
C       VT= TIP VELOCITY FT/SEC
C
C       CONSTANTS BASED ON CLB
C
        K1=(0.9583)/CLB*(1+1.8078*CLB**2)
        K2=PA*10**5/K1
        K3=(0.0025929)/CLB*(1+1.8078*CLB**2)
        K4=553480.0/K1
        K5=3695.7/K1
        DO 100  D=200,300
         DL=D*(0.01)
         I=0
           DO 110  VT=600,700,25
C
C          ARRAY INCREMENTER
           I=I+1
C          WEIGHT EQUATION
C
        W(I)=(K2*(1-(411.51*DL**.75)/(VT**1.5)*(1+K3*VT/DL**.5)**.5)-K4)
       1/(VT+K5*DL**.5)
C
C       CALCULATION OF WE DATA
C
        A=W(I)/DL
        R=(A/3.14)**.5
        P=A**.5/VT
        S=(6.*DL)/(0.0023679*CLB*VT**2)
C
C       ASSUMING A TEETERING SYSTEM
C
        WE(I)=1717.9+1221.*P**.863+266.*P**.7+17449./VT**1.14
       1+2.886*A**.5*P**.57+.191*W(I)**.916+.0294*W(I)**.99
       2+35.15*(W(I)/VT)*(A**.185)*S**.33+.0088*W(I)*A**.21
C          WRITE (5,20) VT
C          WRITE(5,30)R
 110       CONTINUE
           WRITE (2,31)DL,W(1),WE(1),W(2),WE(2)
           WRITE (3,31) DL,W(3),WB(3),W(4),WB(4),W(5),WB(5)
 100    CONTINUE
  90    CONTINUE
C       FORMAT STATEMENTS
 10     FORMAT ('1','CLB=',1F10.4///)
 31     FORMAT (6(2X,F10.3))
        STOP
        END
```

```
C*****************************************************************************
C*****************************************************************************
C   THIS PROGRAM IS DESIGN TO OBTAIN THE GROSS WEIGHT FROM THE               *
C   ASPECT RATIO GRAPH INTERSECTION POINT DATA. IN ORDER TO GRAPH            *
C   THE ASPECT RATIO BOUNDARY ON THE MAIN CARPET PLOT A                      *
C   CORRESPONDING WEIGHT MUST BE OBTAINED. THIS PROGRAM UTILIZES             *
C   THE WEIGHT ESTIMATION FORMULATION FROM THE CARPET PROGRAM.               *
C*****************************************************************************
C*****************************************************************************
C   ASSUMPTIONS:                                                             *
C                    1> ENGINESPECIFIED                                      *
C*****************************************************************************
C*****************************************************************************
C VARIABLE OPTIONS
      REAL*4 VT(5),DL(5),CLR(5),W(5)
      DATA CLR/.625,.575,.535,.460,.42/
      DATA VT/600.,625.,650.,675.,700./
      DATA DL/2.75,2.75,2.72,2.67,2.53/
C-------------------------------------------------------------------------------
      CALL FRTCMS ('FILEDEF ','03      ','DISK    ','CRPTAR',
     >'DATA    ','A       ')
C-------------------------------------------------------------------------------
C
      DO 90 L=1,5
      WRITE(3,10)CLR(L)
      WRITE(3,20)VT(L)
      WRITE(3,30)DL(L)
C     PA= POWER AVAILABLE HP
      PA=206
C     DL= DISK LOADING
C     VT= TIP VELOCITY FT/SEC
C
C     CONSTANTS BASED ON CLR
C
      K1=(0.9583)/CLR(L)*(1+1.8078*CLR(L)**2)
      K2=PA*10**5/K1
      K3=(0.00025929)/CLR(L)*(1+1.8078*CLR(L)**2)
      K4=553480.0/K1
      K5=3695.7/K1
C        WEIGHT EQUATION
C
      W(L)=(K2*(1-(411.51*DL(L)**.75)/(VT(L)**1.5)*
     1(1+K3*VT(L)/DL(L)**.5)**.5)-K4)/(VT(L)+K5*(DL(L)**.5))
      WRITE (3,31)W(L)
 90   CONTINUE
C     FORMAT STATEMENTS
 10   FORMAT ('1','CLR=',1F10.4///)
 20   FORMAT (2X,'VT=',1F10.4///)
 30   FORMAT (2X,'DL=',1F10.4///)
 31   FORMAT (2X,F10.3)
      STOP
      END
```

APPENDIX D. PROGRAMS TO ACCESS HESCOMP

This section contains the control language programs needed to access HESCOMP on the IBM main-frame computer.

```
C***********************************************************************
C***********************************************************************
C******                                                          *******
C**   NOTE!!!! THE PROGRAM INPUT CARDS (DATA LINES) DO NOT HAVE TO   ***
C**      BE IN NUMERICAL ORDER. ERASE THESE COMMENT LINES IF RUNNING ***
C**     PROGRAM                                                      ***
C******                                                          *******
C***********************************************************************
C***********************************************************************
//HESCOMP1 JOB (2399,5555),'AL HANSEN',CLASS=B
//*MAIN ORG=NPGVM1.2399P,LINES=(10)
//     EXEC HESCOMP
//SYSIN DD *
77777
       SAMPLE CASE NO. 1   RUN 1                 1/26/84
120150.               0.              0.               2.              0.
120610.
122310.905
130151.761            0.159           0.               0.032           950.
130651100.            1856.           2000.            2000.           8.
13115870.             1200.           1400.            1600.           1800.
131652000.            2200.           2600.            5.              0.
132140.2              0.4             0.6              0.8
132650.               0.              0.               0.              0.
13325.163             .1676           .1613            .2041           .236
13385.335             .3444           .3725            .4194           .4851
13445.544             .5592           .6049            .6811           .7877
13505.770             .7916           .8562            .964            1.115
135651.0              1.028           1.112            1.252           1.448
136251.2              1.2336          1.3344           1.5024          1.7376
136851.55             1.5934          1.7236           1.9406          2.2444
137458.               870.            1200.            1400.           1600.
137951800.            2000.           2200.            2600.           5.
138450.               0.2             0.4              0.6             0.8
13905.065             .0651           .0653            .067            .071
13965.115             .116            .118             .128            .14
14025.180             .181            .19              .208            .227
14085.26              .261            .273             .295            .325
14145.342             .347            .362             .389            .425
14205.425             .435            .451             .486            .517
14265.5               .511            .53              .56             .61
14325.626             .631            .66              .718            .78
143843.               870.            1600.            2600.
144743.               0.              0.4              0.8
145430.26             0.271           0.29
146030.82             0.84            0.90
146631.09             1.118           1.165
150258.               870.            1200.            1400.           1600.
150751800.            2000.           2200.            2600.           5.
15125C.               0.2             0.4              0.6             0.8
151850.26             0.265           0.271            0.28            0.29
152450.52             0.527           0.54             0.56            0.59
153050.68             0.69            0.705            0.73            0.76
153650.82             0.824           0.84             0.868           0.90
154250.92             0.93            0.95             0.98            1.02
154851.0              1.002           1.02             1.05            1.09
155451.052            1.055           1.07             1.10            1.131
156051.09             1.10            1.118            1.135           1.165
66666
120150.               0.              0.               2.              0.
120610.
122320.905            0.
130151.761            0.159           0.               0.032           950.
130651100.            1856.           2000.            2000.           8.
13115870.             1200.           1400.            1600.           1800.
131652000.            2200.           2600.            5.              0.
132140.2              0.4             0.6              0.8
132650.               0.              0.               0.              0.
13325.163             .1676           .1613            .2041           .236
13385.335             .3444           .3725            .4194           .4851
13445.544             .5592           .6049            .6811           .7877
13505.770             .7916           .8562            .964            1.115
135651.0              1.028           1.112            1.252           1.448
136251.2              1.2336          1.3344           1.5024          1.7376
136851.55             1.5934          1.7236           1.9406          2.2444
137458.               870.            1200.            1400.           1600.
```

```
024622.              1.105
024851.              900.          10.           .075          .97
025310.
02542.82             .80
02572140.            3.
026114.0
026240.              0.2           0.4           0.8
02724.85             .E3           .80           .78
031241130.           .555          .75           1.0
032310.0
032711.02
032821.464COCOCE 066.28
033017.0
033150.0             0.2           0.4           0.6           0.8
033621.0             1.4
03355.006            .0062         .007          .008          .0095
03442.012            .020
260232200.           450.          2000.
26053100.            0.            0.
260E50.              0.            0.            0.            0.
2613525.             25.           25.           0.            0.
2618430.             .18           25.           0.
26225125.            2.08          .04           .8            0.
262751.              0.            2.06          2.0           24.1
263251.0             .75           1.0           .75           0.
2637544.             2.2           61.           .286          1.15
2642514.2            14.2          1.0           1.0           250.
264753.              250.          250.          1.            .11
26522.17             .17
265451.0             1.0           1.0           1.0           1.0
265551.0             1.0           1.0           1.0           1.0
266451.0             1.0           1.0           1.0           1.0
266951.0             1.0           1.0           1.0           1.0
034753.0             3.0           0.0           0.5           1.0
035430.0             0.5           1.0
036131.0             1.0           1.0
036831.0             1.0           1.0
037531.0             1.0           1.0
040110.
04111.0333
042110.
043111.0
044111.105
046121.0             1.0
048120.              0.
05012C.              0.
05112C.              0.
052121.06            1.06
05312.02             .02
054121.105           1.105
05512.1              .2
057121.              1.
059120.              0.
06012.3              .4
061120.              0.
C6212500.            500.
063122.              2.
06412500C.           3000.
065121.105           1.105
066126.              6.
067121.105           1.105
068121.              1.
069120.              0.
070121.              1.
072132.              4.            4.
C7311170.
074130.              0.            0.
07513.5              .5            .5
076130.              0.            0.
0771315.             15.           15.
078132.              2.            2.
0791360.             150.          300.
080131.105           1.105         1.105
C81130.              0.            0.
082131.105           1.105         1.105
083130.              0.            0.
```

13755180C.	2000.	22C0.	2600.	5.
138450.	0.2	0.4	0.6	0.8
13905.065	.0651	.0653	.067	.071
13965.115	.116	.118	.128	.14
14025.180	.181	.19	.208	.227
14085.26	.261	.273	.295	.325
14145.342	.347	.362	.389	.425
14205.425	.435	.451	.486	.517
14265.5	.511	.53	.56	.61
14325.626	.631	.66	.718	.78
143843.	870.	1600.	2600.	
144743.	0.	0.4	0.8	
145430.26	0.271	0.29		
146030.82	0.84	0.90		
146631.09	1.118	1.165		
150258.	870.	1200.	1400.	1600.
15075180C.	2000.	2200.	2600.	5.
151250.	0.2	0.4	0.6	0.8
151850.26	0.265	0.271	0.28	0.29
152450.52	0.527	0.54	0.56	0.59
153050.68	0.69	0.705	0.73	0.76
153650.82	0.824	0.84	0.868	0.90
154250.92	0.93	0.95	0.98	1.02
154851.0	1.002	1.02	1.05	1.09
155451.052	1.055	1.07	1.10	1.131
156051.09	1.10	1.118	1.135	1.165
66666				
160123.0	-9.0			
16035.0074918	-.028	.262	.276	2.45
16081.865				
16095.0079059	2.82	.09	1.17	.00124
16142.758	.743			
1616510.	0.	.004	.007	.009
16215.010	.011	.0115	.012	.0155
16265.022	1.018	1.065	1.154	1.233
163151.279	1.314	1.327	1.337	1.364
163611.357				
000151.	1.	2.	0.	1.
000654.	4.	1.	1.	3.
001151.	2.	0.	1.	1.
001642.	2.	2.	0.	
002252.	25000.	0.	0.	0.
002750.	.33	220.	220.	3.5
003251.0	0.0	1.05	1.0	2.0
003754.0	3.0	4.0	9.0	2.0
004258.0	6.0	3.0	4.0	60.
C0471100.				
010310.5				
01055.20	.12	0.	.5	1.0
01105.2	.8	4.0	1.15	.12
01152.0162	.5			
012050.0	0.0	7.0	6.5	1.3
012551.C	12.	0.	.55	5.
01302.3	1.1			
01365.45	.15	.8	.85	.5
01415180.	.035	2.0	.078	0.1
01465.035	2.0	.078	0.	0.
01511.1				
01525.4	.2	.5	.4	3.
017133.	1.	11.		
017654.	-9.	.25	.075	.1
C1815725.	.12	1.06	165.	3000.
0186543.2	.110	1.75	1.35	1.0
019131.53	0.	.85		
020355.	-4.	.3	.075	690.
02085.17	.30	.75	1.00	.72
021331.00	1.0	1.05		
021610.				
021711.761				
021932.0	2.0	1.0		
02235.97	100.	1.0	1.0	4000.
022851.06	50.3	1.105	0.0	.95
023350.0	2.0	3000.	170.	43.2
023841.105	.75	.30	0.	
024211.761				
024511.0				

```
08413.55          .60          .70
085130.           0.           0.
1C3120.           0.
10412.4           .4
1C5120.           0.
10612.05          .05
107121.105        1.105
10812.5           .25
109121.105        1.105
110120.0          0.0
11111.35
112120.0          0.0
113120.0          0.0
11611-1000.
11711.01
118111000.
119111.0
88888
99999
/*
//
```

APPENDIX E: HESCOMP INPUT AND OUTPUT EXAMPLES

This section contains samples of the IBM computer input and output.

H E S C O M P
HELICOPTER SIZING & PERFORMANCE COMPUTER PROGRAM E-

THE FOLLOWING IS A CARD BY CARD REPRODUCTION OF THE INPUTS THIS CASE

```
LOC.   CORRESPONDS TO LOCATION NUMBER GIVEN ON INPUT SHEET
NUM    STANDS FOR THE NUMBER OF SEQUENTIAL INPUT VALUES STARTINGC.  (MAX. =5)
VAL    EQUALS VALUE FOR VARIABLE CORRESPONDING TO LOC.
VAL1          VALUE            CORRESPONDING TO LOC.+0001
VAL2          VALUE            CORRESPONDING TO LOC.+0002
       ETC.
```

NOTE : IN USING AUXILIARY ENGINES ; AUXILIARY ENGINE CYCLLOCATIONS CAN BE CREATED BY PLACING A 66666 CARD IN FRONT AND BEHIND A STANDARD ENIE

LOC.	NUM	VAL	VAL1	VA	VAL3	VAL4
1201	5	.0	.0	.0	2.0000	.0
1206	1	.0				
1223	1	.90500				
1301	5	1.7610	.15900	.0	.32000E-01	950.00
1306	5	1100.0	1856.0	200	2000.0	8.0000
1311	5	870.00	1200.0	140	1600.0	1800.0
1316	5	2000.0	2200.0	260	5.0000	.0
1321	4	.20000	.40000	.60	.80000	
1326	5	.0	.0	.0	.0	.0
1332	5	.16300	.16700	.18	.20410	.23600
1338	5	.33500	.34440	.37	.41940	.48510
1344	5	.54400	.55920	.60	.68110	.78770
1350	5	.77000	.79160	.85	.96400	1.1150
1356	5	1.0000	1.0280	1.1	1.2520	1.4480
1362	5	1.2000	1.2336	1.3	1.5024	1.7376
1368	5	1.5500	1.5934	1.7	1.9406	2.2444
1374	5	8.0000	870.00	120	1400.0	1600.0
1379	5	1800.0	2000.0	220	2600.0	5.0000
1384	5	.0	.20000	.40	.60000	.80000
1390	5	.65000E-01	.65100E-01	.65	.67000E-01	.71000E-01
1396	5	.11500	.11600	.11	.12800	.14000
1402	5	.18000	.18100	.19	.20800	.22700
1408	5	.26000	.26100	.27	.29500	.32500
1414	5	.34200	.34700	.36	.38900	.42500
1420	5	.42500	.43500	.45	.48600	.51700
1426	5	.50000	.51100	.53	.56000	.61000
1432	5	.62600	.63100	.66	.71800	.78000
1438	4	3.0000	870.00	160	2600.0	
1447	4	3.0000	.0	.40	.80000	
1454	3	.26000	.27100	.29		
1460	3	.82000	.84000	.90		
1466	3	1.0900	1.1180	1.1		
1502	5	8.0000	870.00	120	1400.0	1600.0
1507	5	1800.0	2000.0	220	2600.0	5.0000
1512	5	.0	.20000	.40	.60000	.80000
1518	5	.26000	.26500	.27	.28000	.29000
1524	5	.52000	.52700	.54	.56000	.59000
1530	5	.68000	.69000	.70	.73000	.76000
1536	5	.82000	.82400	.84	.86800	.90000
1542	5	.92000	.93000	.95	.98000	1.0200
1548	5	1.0000	1.0020	1.0	1.0500	1.0900
1554	5	1.0520	1.0550	1.0	1.1000	1.1310
1560	5	1.0900	1.1000	1.1	1.1350	1.1650
2201	5	.0	.0	.0	2.0000	.0
2206	1	.0				

2223	2	.90500	.0			
2301	5	1.7610	.15900	.0	.32000E-01	950.00
2306	5	1100.0	1850.0	200	2000.0	8.0000
2311	5	870.00	1200.0	140	1600.0	1800.0
2316	5	2000.0	2200.0	260	5.0000	.0
2321	4	.20000	.40000	.60	.80000	
2326	5	.0	.0	.0	.0	.0
2332	5	.16300	.16760	.18	.20410	.23600
2338	5	.33500	.34440	.37	.41940	.48510
2344	5	.54400	.55920	.60	.68110	.78770
2350	5	.77000	.79160	.85	.96400	1.1150
2356	5	1.0000	1.0280	1.1	1.2520	1.4480
2362	5	1.2000	1.2336	1.3	1.5024	1.7376
2368	5	1.5500	1.5934	1.7	1.7406	2.2444
2374	5	8.0000	870.00	120	1400.0	1600.0
2379	5	1800.0	2000.0	220	2600.0	5.0000
2384	5	.0	.20000	.40	.60000	.80000
2390	5	.65000E-01	.65100E-01	.65	.67000E-01	.71000E-01
2396	5	.11500	.11600	.11	.12800	.14000
2402	5	.18000	.18100	.19	.20800	.22700
2408	5	.26000	.26100	.27	.23500	.32500
2414	5	.34200	.34700	.36	.38900	.42500
2420	5	.42500	.43500	.45	.48600	.51700
2426	5	.50000	.51100	.53	.56000	.61000
2432	5	.62600	.63100	.66	.71800	.78000
2438	4	3.0000	870.00	160	2600.0	
2447	4	3.0000	.0	.40	.80000	
2454	3	.26000	.27100	.29		
2460	3	.82000	.84000	.90		
2466	3	1.0900	1.1180	1.1		
2502	5	8.0000	870.00	120	1400.0	1600.0
2507	5	1800.0	2000.0	220	2600.0	5.0000
2512	5	.0	.20000	.40	.60000	.80000
2518	5	.26000	.26500	.27	.28000	.29000
2524	5	.52000	.52700	.54	.56000	.59000
2530	5	.68000	.69000	.70	.73000	.76000
2536	5	.82000	.82400	.84	.86800	.90000
2542	5	.92000	.93000	.95	.98000	1.0200
2548	5	1.0000	1.0020	1.0	1.0500	1.0900
2554	5	1.0520	1.0550	1.0	1.1000	1.1310
2560	5	1.0900	1.1000	1.1	1.1350	1.1650
1601	2	3.0000	-9.0000			
1603	5	.74918E-02	-.28000E-01	.26	.27600	2.4500
1608	1	.86500				
1609	5	.79059E-02	2.8200	.90	1.1700	.12400E-02
1614	2	.75600	.74300			
1616	5	10.000	.0	.40	.70000E-02	.90000E-02
1621	5	.10000E-01	.11000E-01	.11	.12000E-01	.15500E-01
1626	5	.22000E-01	1.0180	1.0	1.1540	1.2330
1631	5	1.2790	1.3140	1.3	1.3370	1.3640
1636	1	1.3970				
1	5	1.0000	1.0000	2.0	.0	1.0000
6	5	4.0000	4.0000	1.0	1.0000	3.0000
11	5	1.0000	2.0000	.0	1.0000	1.0000
16	4	2.0000	2.0000	2.0	.0	
22	5	2.0000	25000.	.0	.0	.0
27	5	.0	.33000	220	220.00	3.5000
32	5	1.0000	.0	1.0	1.0000	2.0000
37	5	4.0000	3.0000	4.0	9.0000	2.0000
42	5	8.0000	6.0000	3.0	4.0000	60.000
47	1	100.00				
103	1	.50000				
105	5	.20000	.12000	.0	.50000	1.0000
110	5	.20000	.80000	4.0	1.1500	.12000

115	2	.16200E-01	.50000			
120	5	.0	.0	7.0	6.5000	1.3000
125	5	1.0000	12.000	.0	.55000	5.0000
130	2	.30000	1.1000			
136	5	.45000	.15000	.80	.85000	.50000
141	5	180.00	.35000E-01	2.0	.73000E-01	.10000
146	5	.35000E-01	2.0000	.78	.0	.0
151	1	.10000				
152	5	.40000	.20000	.50	.40000	3.0000
171	3	3.0000	1.0000	11.		
176	5	4.0000	-9.0000	.25	.75000E-01	.10000
181	5	725.00	.12000	1.0	165.00	3000.0
186	5	43.200	.11000	1.7	1.3500	1.0000
191	3	1.5300	.0	.65		
203	5	5.0000	-4.0000	.30	.75000E-01	690.00
208	5	.17000	.30000	.75	1.0000	.72000
213	3	1.0000	1.0000	1.0		
216	1	.0				
217	1	1.7610				
219	3	2.0000	2.0000	1.0		
223	5	.97000	100.00	1.0	1.0000	4000.0
228	5	1.0000	50.300	1.1	.0	.95000
233	5	.0	2.0000	300	170.00	43.200
238	4	1.1050	.75000	.30	.0	
242	1	1.7610				
245	1	1.0000				
246	2	2.0000	1.1050			
248	5	1.0000	900.00	10.	.75000E-01	.97000
253	1	.0				
254	2	.82000	.30000			
257	2	140.00	3.0000			
261	1	4.0000				
262	4	.0	.20000	.40	.80000	
272	4	.85000	.83000	.80	.78000	
312	4	1130.0	.55500	.75	1.0000	
323	1	.0				
327	1	1.0200				
328	2	.14640E+07	6.2800			
330	1	7.0000				
331	5	.0	.20000	.40	.60000	.80000
336	2	1.0000	1.4000			
339	5	.60000E-02	.62000E-02	.70	.80000E-02	.95000E-02
344	2	.12000E-01	.20000E-01			
2602	3	2200.0	450.00	200		
2605	3	100.00	.0	.0		
2608	5	.0	.0	.0	.0	.0
2613	5	25.000	25.000	25.	.0	.0
2618	4	30.000	.18000	25.	.0	
2622	5	125.00	2.0800	.40	.80000	.0
2627	5	1.0000	.0	2.0	2.0000	24.100
2632	5	1.0000	.75000	1.0	.75000	.0
2637	5	44.000	2.2000	61.	.28600	1.1500
2642	5	14.200	14.200	1.0	1.0000	250.00
2647	5	3.0000	250.00	250	1.0000	.11000
2652	2	.17000	.17000			
2654	5	1.0000	1.0000	1.0	1.0000	1.0000
2659	5	1.0000	1.0000	1.0	1.0000	1.0000
2664	5	1.0000	1.0000	1.0	1.0000	1.0000
2669	5	1.0000	1.0000	1.0	1.0000	1.0000
347	5	3.0000	3.0000	.0	.50000	1.0000
354	3	.0	.50000	1.0		
361	3	1.0000	1.0000	1.0		
368	3	1.0000	1.0000	1.0		

375	3	1.0000	1.0000	1.0
401	1	.0		
411	1	.33300E-01		
421	1	.0		
431	1	1.0000		
441	1	1.1050		
461	2	1.0000	1.0000	
481	2	.0	.0	
501	2	.0	.0	
511	2	.0	.0	
521	2	1.0600	1.0600	
531	2	.20000E-01	.20000E-01	
541	2	1.1050	1.1050	
551	2	.10000	.20000	
571	2	1.0000	1.0000	
591	2	.0	.0	
601	2	.30000	.40000	
611	2	.0	.0	
621	2	500.00	500.00	
631	2	2.0000	2.0000	
641	2	5000.0	3000.0	
651	2	1.1050	1.1050	
661	2	6.0000	6.0000	
671	2	1.1050	1.1050	
681	2	1.0000	1.0000	
691	2	.0	.0	
701	2	1.0000	1.0000	
721	3	2.0000	4.0000	4.0
731	1	170.00		
741	3	.0	.0	.0
751	3	.50000	.50000	.50
761	3	.0	.0	.0
771	3	15.000	15.000	15.
781	3	2.0000	2.0000	2.0
791	3	60.000	150.00	300
801	3	1.1050	1.1050	1.1
811	3	.0	.0	.0
821	3	1.1050	1.1050	1.1
831	3	.0	.0	.0
841	3	.55000	.60000	.70
851	3	.0	.0	.0
1031	2	.0	.0	
1041	2	.40000	.40000	
1051	2	.0	.0	
1061	2	.50000E-01	.50000E-01	
1071	2	1.1050	1.1050	
1081	2	.50000	.25000	
1091	2	1.1050	1.1050	
1101	2	.0	.0	
1111	1	.35000		
1121	2	.0	.0	
1131	2	.0	.0	
1161	1	-1000.0		
1171	1	.10000E-01		
1181	1	1000.0		
1191	1	1.0000		

```
WG = 0.250000E+05  WFA = 0.0           WFR = 0.0
WG = 0.250000E+05  WFA = 0.738579E+04  WFR = 0.512283E+04
WG = 0.217672E+05  WFA = 0.580161E+04  WFR = 0.453304E+04
```

H E S C O M P
HELICOPTER SIZING & PERFORMANCE COMPUTER PROGRAM E-

SINGLE ROTOR
COMPOUND HELICOPTER
AUX. INDEPENDENT I/SHAFT CRUISION

S I Z E D A T A THIS RUN CONVERGED IN 3 ITERATIONS

GROSS WEIGHT = 17643. LB

FUSELAGE

LF	LENGTH(BODY+TAILBOOM)	50.1	FT.
LC	LENGTH(CABIN)	12.0	FT.
LB	LENGTH(BODY)	27.5	FT.
LTB	LENGTH(TAILBOOM)	22.6	FT.
XM	FWD. ROTOR LOCATION	15.1	FT.
WF	WIDTH	6.5	FT.
SF	WETTED AREA	737.5	SQ. FT.

WING

AR	ASPECT RATIO	4.51	
SW	AREA	113.3	SQ. FT.
BW	SPAN	22.6	FT.
CBARW	MEAN CHORD	5.0	FT.
LAMBDA C/4	QUARTER CHORD SWEEP	0.0	DEG.
LAMBDA	TAPER RATIO	0.500	
(T/C)R	ROOT THICKNESS/CHORD	0.200	
(T/C)T	TIP THICKNESS/CHORD	0.120	
WG/SW	WING LOADING	155.7	LBS/SQ. FT.
GRW	ROTOR/WING GAP	8.6	FT.
CF/C	FLAP CHORD/MEAN CHORD RATIO	1.000	

HOR. TAIL

ARHT	ASPECT RATIO	4.000	
SHT	AREA	35.5	SQ. FT.
BHT	SPAN	11.9	FT.
CBARHT	MEAN CHORD	3.0	FT.
LAMBDA H	TAPER RATIO	0.500	
(T/C)HT	THICKNESS/CHORD	0.120	
LTH	HOR. TAIL ARM	26.0	FT.

VERT. TAIL

ARVT	ASPECT RATIO	1.523	
SVT	AREA	21.2	SQ. FT.
BVT	SPAN	5.7	FT.
CBARVT	MEAN CHORD	3.7	FT.
LAMBDA VT	TAPER RATIO	0.450	
ZTR	TAIL ROTOR(VERT.) LOCATION	4.6	FT.
ZETAVT	TAIL ROTOR/VERT. TAIL OVERLAP RATIO	0.800	
(T/C)VT	THICKNESS/CHORD	0.150	

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                              H E S C O M P
        HELICOPTER SIZING & PERFORMANCE COMPUTER PROGRAM     E-

    SINGLE ROTOR
            COMPOUND HELICOPTER
                          AUX. INDEPENDENT T/SHAFT CRUISISION

S I Z E   D A T A   THIS RUN CONVERGED IN  3 ITERATIONS

                        GROSS WEIGHT =   17643.   LB
      FUSELAGE

        LF          LENGTH(BODY+TAILBOOM)                 50.1 FT.
        LC          LENGTH(CABIN)                         12.0 FT.
        LB          LENGTH(BODY)                          27.5 FT.
        LTB         LENGTH(TAILBOOM)                      22.6 FT.
        XM          FWD. ROTOR LOCATION                   15.1 FT.
        WF          WIDTH                                  6.5 FT.
        SF          WETTED AREA                          737.5 SQ. FT.

      WING

        AR          ASPECT RATIO                          4.51
        SW          AREA                                 113.3 SQ. FT.
        BW          SPAN                                  22.6 FT.
        CBARW       MEAN CHORD                             5.0 FT.
        LAMBDA C/4  QUARTER CHORD SWEEP                    0.0 DEG.
        LAMBDA      TAPER RATIO                          0.500
        (T/C)R      ROOT THICKNESS/CHORD                 0.200
        (T/C)T      TIP THICKNESS/CHORD                  0.120
        WG/SW       WING LOADING                         155.7 LBS/SQ. FT.
        GRW         ROTOR/WING GAP                         8.6 FT.
        CF/C        FLAP CHORD/MEAN CHORD RATIO          1.000
      HOR. TAIL

        ARHT        ASPECT RATIO                         4.000
        SHT         AREA                                  35.5 SQ. FT.
        BHT         SPAN                                  11.9 FT.
        CBARHT      MEAN CHORD                             3.0 FT.
        LAMBDA H    TAPER RATIO                          0.500
        (T/C) HT    THICKNESS/CHORD                      0.120
        LTH         HOR. TAIL ARM                         26.0 FT.
      VERT. TAIL

        ARVT        ASPECT RATIO                         1.523
        SVT         AREA                                  21.2 SQ. FT.
        BVT         SPAN                                   5.7 FT.
        CBARVT      MEAN CHORD                             3.7 FT.
        LAMBDA VT   TAPER RATIO                          0.450
        ZTR         TAIL ROTOR(VERT.) LOCATION             4.6 FT.
        ZETAVT      TAIL ROTOR/VERT. TAIL OVERLAP RATIO  0.800
        (T/C) VT    THICKNESS/CHORD                      0.150
```

MAIN ROTOR PYLON

AR	ASPECT RATIO	0.500	
SPP	WETTED AREA	39.1	SQ. FT.
FAPP	FRONTAL AREA	6.2	SQ. FT.
HP1	HEIGHT	3.0	FT.
CBARPP	MEAN CHORD	6.0	FT.
LAMBDA PP	TAPER RATIO	0.400	
(T/C)R	ROOT THICKNESS/CHORD	0.400	
(T/C)T	TIP THICKNESS/CHORD	0.200	

PRIMARY ENGINE NACELLE

LN	LENGTH	5.8	FT.
DN	MEAN DIAMETER	2.	FT.
SN	WETTED AREA(TOTAL FOR ALL ENGINES)	60.8	SQ. FT.

AUXILIARY INDEPENDENT ENGINE NACELLE

LNI	LENGTH	4.3	FT.
DNI	MEAN DIAMETER	1.	FT.
SNI	WETTED AREA(TOTAL FOR ALL ENGINES)	19.	SQ. FT.

AUXILIARY INDEPENDENT ENGINE NACELLE STRUT

SSTR	WETTED AREA(TOTAL)	0.	SQ. FT.
BNS	SPAN	0.1	FT.
CNS	MEAN CHORD	2.8	FT.

PROPELLER(AUXILIARY PROPULSION)

DAB	DIAMETER	10.0	FT.
AF	ACTIVITY FACTOR PER BLADE	140.0	
SIGAR	SOLIDITY	0.171	
NRA	NO. OF PROPELLERS	1.	
NO. BLADES	NO. OF BLADES/PROP	3.	
VTIP	TIP SPEED	900.	FT./SEC

MAIN ROTOR

DMR	DIAMETER	45.2	FT.
SIGMR	SOLIDITY	0.128	
WG/A	DISC LOADING	11.0	LB/SQ. FT.
CT/SIGMA	THRUST COEFF./SOLIDITY	0.110	
NR	NO. OF ROTORS	1.	
NO. BLADES	NO. OF BLADES/ROTOR	4.	
THETA	BLADE TWIST	-9.000	DEG.
XC	BLADE CUTOUT/RADIUS RATIO	0.250	
VTIP	TIP SPEED	725.	FT./SEC.

TAIL ROTOR

DTR	DIAMETER	10.8	FT.
SIGTR	SOLIDITY	0.237	
(T/A)NET	NET DISC LOADING	17.8	LB./SQ. FT.
CT/SIGMA	THRUST COEFF./SOLIDITY	0.170	
NO. BLADES	NO. OF BLADES/ROTOR	5.	
THETA	BLADE TWIST	-4.000	DEG.
XCTR	BLADE CUTOUT/RADIUS RATIO	0.300	
G	MAIN/TAIL ROTOR GAP	1.0	FT.
VTIP	TIP SPEED	690.	FT./SEC.

```
W E I G H T S   D A T A     IN LBS

       MLF            MANEUVER LOAD FACTOR
       GLF            GUST LOAD FACTOR
       ULF            ULTIMATE LOAD FACTOR

   PROPULSION GROUP
           WMRG       TOTAL MAIN ROTOR GROUP                          .
       K12 WMRB           MAIN ROTOR BLADE (PER ROTOR)             1023.
       K13 WMRH           MAIN ROTOR HUB (PER ROTOR)                511.
           WBF            BLADE FOLDING(PER ROTOR)                  230.
       K15 WAR        AUXILIARY PROPULSION ROTOR GROUP                .
           WDS        DRIVE SYSTEM                                    .
       K16 WMRDS          MAIN ROTOR DRIVE SYSTEM                  1359.
       K20 WTRDS          TAIL ROTOR DRIVE SYSTEM                   118.
       K17 WAPDS          AUXILIARY PROPULSION DRIVE SYSTEM         205.
       K18 WEP        PRIMARY ENGINES                                 .
       K19 WEA        AUXILARY ENGINES                                .
           WPEI       PRIMARY ENGINE INSTALLATION                     .
           WAEI       AUXILIARY ENGINE INSTALLATION                   .
           WFS        FUEL SYSTEM                                     .
       DELTA WP       PROPULSION GROUP WEIGHT INCREMENT               .
             WP    TOTAL PROPULSION GROUP WEIGHT                               5091.

   STRUCTURES GROUP
       K8  WW         WING                                            .
           WTG        TAIL GROUP                                      .
       K9  WHT            HOR. TAIL                                  71.
       K14 WTR            TAIL ROTOR                                123.
       K6  WB         FUSELAGE                                        .
       K7  WLG        LANDING GEAR                                    .
           WNG            NOSE GEAR                                 141.
           WMG            MAIN GEAR                                 565.
           WTES       TOTAL ENGINE SECTION                            .
           WPES           PRIMARY ENGINE SECTION                    145.
           WAES           AUXILIARY ENGINE SECTION                   51.
       DELTA WST      STRUCTURE WEIGHT INCREMENT                      .
             WST   TOTAL STRUCTURE WEIGHT                                      3272.

   FLIGHT CONTROLS GROUP
           WPFC       PRIMARY FLIGHT CONTROLS                         .
           WCC            COCKPIT CONTROLS                           81.
       K1  WRC            MAIN ROTOR CONTROLS                       356.
       K2  WSC            MAIN ROTOR SYSTEMS CONTROLS               248.
       K3  WFW            FIXED WING CONTROLS                         0.
           WTM            TILT MECHANISM                              0.
           WSAS           SAS                                        30.
           WAFC       AUXILIARY FLIGHT CONTROLS                       .
       K4  WRCA           AUX. PROPULSION ROTOR CONTROLS             24.
       K5  WSCA           AUX. PROPULSION ROTOR SYS. CONTRO          32.
           WMC            MISCELLANEOUS CONTROLS                      0.
       DELTA WFC      CONTROL WEIGHT INCREMENT                        .
             WFC   TOTAL CONTROL WEIGHT                                         870.
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WFE	WEIGHT OF FIXED EQUIPMENT	2200.
WE	WEIGHT EMPTY	11433.
WFUL	FIXED USEFUL LOAD	450.
OWE	OPERATING WEIGHT EMPTY	11883.
WPL	PAYLOAD	2000.
(WF)A	FUEL	3760.
WG	GROSS WEIGHT	17643.

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AERODYNAMICS DATA
        FE              TOTAL EFFECTIVE FLATPLATE AREA                    SQFT
        SWET            TOTAL WETTED AREA                                 SQFT
        CEAFF           MEAN SKIN FRICTION COEFF.
     DRAG  BREAKDOWN             IN  SQFT
        FEW             WING FE                                  .729
        FEF             FUSELAGE FE                              .233
        FEFL            FORWARD(MAIN) ROTOR PYLON FE             .0
        FEAF            AFT ROTOR PYLON FE                       .0
        FEMBH           MAIN ROTOR HUB(S) FE                     .0
        FETRH           TAIL ROTOR HUB FE                        .0
        FEVT            VERTICAL TAIL FE                         .0
        FEHT            HORIZONTAL TAIL FE                       .0
        FEN             PRIMARY ENGINE NACELLE FE                .0
        FENI            AUX. INDEPENDENT CRUISE ENG. NAC. FE     .0
        FENS            AUX. INDEPENDENT CRUISE ENG. STRUT FE    .0
        DELTA FE        INCREMENTAL FE                           .0
AERODYNAMIC  COEFF.
        A5                                                       79
        A6                                                       64
        A7                                                       20
        A8                                                       13
        A9                                                       48
        E        WING LIFT EFFICIENCY FACTOR                   C.
        EVT      VERTICAL TAIL LIFT EFFICIENCY FACTOR          0.
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R O T O R   D A T A

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ROTOR CYCLE NO.     3.0000

MAIN ROTOR SOLIDITY SIZED BY MANUEVER CONDITIONS
H =     3000.0 FT. , TEMP =       91.5 DEG. , V =     KT.
100.0 PERCENT HOVER RPM
ROTOR MANUEVER G'S =  1.350 , CT/SIGMA = 0.110

TAIL ROTOR SIZED AT       1.050 TIMES THE SOLIDITY
REQUIRED TO SATISFY HOVERING TURN REQUIREMENTS AT :
                    H                               =      4000
                    TEMP                            =      95.0F.
                    CTG/CTNET                       =       1.2
                    YAW RATE                        =      0.7SEC.
                    YAW ACCELERATION                =      0.3SEC2
                    TAIL ROTOR POLAR
                    MOM. OF INERTIA(PER BLADE)      =       4.1FT2
                    HELICOPTER YAW
                    MOM. OF INERTIA                 =     36385FT2
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P R O P U L S I O N   D A T A
        PRIMARY PROPULSION CYCLE NO.     1.761
                TURBOSHAFT ENGINE

                 2.  ENGINES

            BHP*E          MAX. STANDARD S.L. STATIC H.P.            H.P.

            ENGINE SIZED FOR TAKEOFF AT T/W =1.06
             95.0 PERCENT MILITARY POWER SETTING,
            H = 4000. FT, TEMPERATURE = 95.04 DEG.F.,
             0.0   ENGINES INOPERATIVE, AND    0.0  FT/MIN VERTI OF CLIMB.

        AUX. INDEPENDENT PROPULSION CYCLE NO.     1.761
                TURBOSHAFT ENGINE

                 1.  ENGINES

            BHP*PI          MAX. STANDARD S.L. STATIC H.P.      .     H.P.

            ENGINE SIZED FOR CRUISE AT VC = 170. KNOTS,
             NORMAL  POWER SETTING,
            HC =  3000. FT, TEMPERATURE =  91.50 DEG.F.,
            AND  0.0   ENGINES INOPERATIVE.

                MAIN AND TAIL ROTOR DRIVE SYSTEM RATING          H.P.

                MAIN ROTOR DRIVE SYSTEM RATING         2914.

        XMSN SIZED AT 100. PERCENT OF MAIN ROTOR HOVER POWER REQ
        AT H = 4000. FT, TEMP = 95.04 DEG.F., 100.0 PERCENT HOVE

                TAIL ROTOR DRIVE SYSTEM RATING          436.

        XMSN SIZED AT 100. PERCENT OF TAIL ROTOR HOVER POWER REQ
        AT H = 4000. FT, TEMP = 95.04 DEG.F., 100.0 PERCENT HOVE

                AUXILIARY INDEPENDENT PROPULSION DRIVE SYSTEM RA        871.     H.P.

        XMSN SIZED AT 100. PERCENT OF AUX. PROPULSION CRUISE POWRE  AT VC =170. KT,
        HC =  3000. FT, TEMP= 91.50 DEG.F.
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H E S C O M P
HELICOPTER SIZING & PERFORMANCE COMPUTER PROGRAM E-

MISSION PERFORMANCE DATA

TAXI FOR 0.033 HRS. AT GROUND IDLE ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRESS. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	TOTAL FUEL FLOW (LBS/HR)	AUX. TURB. TEMP. (R)	AUX. ENG. CODE	AUX. ENG. PERF	AUX. ENG. FUEL FLOW (LBS/HR)	TEMP. DEG. (F)
0.0	0.0	0.0	17643.	0.	0.0	950.0	T	438.	550.0	T	0.0	95.	59.0
0.033	0.0	14.6	17628.	0.	0.0	950.0	T	438.	550.0	T	0.0	95.	59.0

TAKEOFF, HOVER, OR LAND AT T/W = 1.060 FOR 0.100 HRS.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	TOTAL FUEL FLOW (LBS/HR)	THRUST TO WEIGHT	FM	BHP	CT	CT/SIGMA
M.ROTOR VTIP	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	VRC RHP	PRIM.ENG FUEL FLOW (LBS/HR)	AUX.ENG FUEL FLOW (LBS/HR)	ROTLI CODE	TEMP DEG. (F)	DELDCM	FMI	CPPRC	CPIND	CDC
0.033	0.0	14.6	17628.	0.	0.0	1685.7	P	1527.	1.060	0.705	2889.	0.0093	0.073
725.0	2387.	690.0	318.	0.	1432.	95.	A	59.0	0.0	0.705	0.00011	0.0079	0.0068
0.053	0.0	45.1	17598.	0.	0.0	1684.2	P	1524.	1.060	0.705	2881.	0.0093	0.073
725.0	2380.	690.0	317.	0.	1429.	95.	A	59.0	0.0	0.705	0.00011	0.0079	0.0068
0.073	0.0	75.6	17567.	0.	0.0	1682.8	P	1521.	1.060	0.705	2872.	0.0093	0.073
725.0	2373.	690.0	316.	0.	1427.	95.	A	59.0	0.0	0.705	0.00011	0.0079	0.0068
0.093	0.0	106.0	17537.	0.	0.0	1681.3	P	1519.	1.060	0.705	2864.	0.0093	0.072
725.0	2367.	690.0	314.	0.	1424.	95.	A	59.0	0.0	0.705	0.00011	0.0079	0.0068
0.113	0.0	136.4	17507.	0.	0.0	1679.9	P	1516.	1.060	0.705	2856.	0.0093	0.072
725.0	2360.	690.0	313.	0.	1421.	95.	A	59.0	0.0	0.705	0.00011	0.0078	0.0068
0.133	0.0	166.7	17476.	0.	0.0	1678.5	P	1513.	1.060	0.705	2848.	0.0092	0.072
725.0	2353.	690.0	312.	0.	1418.	95.	A	59.0	0.0	0.705	0.00011	0.0078	0.0068
0.133	0.0	166.7	17476.	0.	0.0	1678.5	P	1513.	1.060	0.705	2848.	0.0092	0.072
725.0	2353.	690.0	312.	0.	1418.	95.	A	59.0	0.0	0.705	0.00011	0.0078	0.0068

CRUISE AT 170.0 KNOTS TAS, LIMITED BY NORMAL ENGINE RATING

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	EAS (KTS)	MU	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	SPEC. RANGE (NM/LB)	BHP
M.ROTOR VTIP (FPS)	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP PROP	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PERF		AUX. ENG. BHP OR THRUST
CPPRO	CPIND	CPPAR	CPNUD	CDO	DELCDS	DELCDM	CXR	J	CP	CT	CLW	CDW	KN
0.133	0.0	166.7	17476.	0.	170.0	1604.6	P	170.0	0.396	0.046	-5.0	.10066	2545.
725.0	2216.	650.0	156.	----	1239.	----	0.821	400.	1679.4	P	0.620		1119.
0.000478	0.000049	0.000269	0.000042	0.01735	0.00012	0.00933	0.000517	----	----	----	0.500	0.007	0.682
0.222	15.00	315.7	17327.	0.	170.0	1602.8	P	170.0	0.396	0.046	-5.0	.100[illegible]	2534.
725.0	2206.	650.0	155.	----	1235.	----	0.821	400.	1679.0	P	0.619		1119.
0.000476	0.000048	0.000269	0.000042	0.01727	0.00010	0.00927	0.000517	----	----	----	0.500	0.0[illegible]	0.680
0.310	30.00	464.4	17179.	0.	170.0	1600.9	P	170.0	0.396	0.045	-5.1	.10116	2523.
725.0	2195.	650.0	155.	----	1281.	----	0.821	400.	1678.5	P	0.618		1119.
0.000474	0.000047	0.000269	0.000041	0.01720	0.00009	0.00921	0.000516	----	----	----	0.503	0.007	0.677
0.398	45.00	612.7	17030.	0.	170.0	1599.1	P	170.0	0.396	0.045	-5.1	.10140	2512.
725.0	2185.	650.0	154.	----	1277.	----	0.821	399.	1678.0	P	0.618		1119.
0.000472	0.000046	0.000268	0.000041	0.01713	0.00008	0.00915	0.000516	----	----	----	0.500	0.007	0.674
0.486	60.00	760.6	16882.	0.	170.0	1597.3	P	170.0	0.396	0.044	-5.2	.101[illegible]	2501.
725.0	2175.	650.0	154.	----	1273.	----	0.821	399.	1677.6	P	0.617		1119.
0.000471	0.000044	0.000268	0.000040	0.01707	0.00008	0.00909	0.000515	----	----	----	0.500	0.007	0.671

CRUISE AT SPEED FOR 99 PER CENT BEST RANGE WITH HEADWIND OF 0.0

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	EAS (KTS)	MU	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	SPEC. RANGE (NMPP)	BHP
M.ROTOR VTIP (FPS)	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP PROP	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PERF		AUX. ENG. BHP OR THRUST
CPFRC	CPINC	CPPAR	CPNUD	CDO	DELCDS	DELCDM	CXR	J	CP	CT	CLW	CDW	RN
0.597	67.95	845.5	16797.	5000.	149.1	1517.6	P	138.4	0.347	0.059	-2.8	.11667	1877.
725.0	1616.	690.0	108.	----	994.	----	0.826	285.	1538.1	P	0.471		549.
0.000412	0.000092	0.000153	0.000054	0.01654	0.00021	0.00843	0.000371	----	----	----	0.500	0.007	0.781
0.668	82.95	974.1	16669.	5000.	149.1	1515.6	P	138.4	0.347	0.059	-2.8	.11700	1867.
725.0	1666.	690.0	107.	----	991.	----	0.826	285.	1537.7	P	0.471		548.
0.000410	0.000090	0.000152	0.000054	0.01647	0.00019	0.00837	0.000370	----	----	----	0.500	0.007	0.779
0.768	97.95	1102.3	16541.	5000.	149.1	1513.6	P	138.4	0.347	0.058	-2.9	.11734	1856.
725.0	1557.	690.0	107.	----	987.	----	0.826	284.	1537.3	P	0.470		547.
0.000408	0.000088	0.000152	0.000053	0.01640	0.00018	0.00832	0.000370	----	----	----	0.500	0.007	0.778
0.889	112.95	1230.2	16413.	5000.	149.1	1511.6	P	138.4	0.347	0.058	-2.9	.11766	1846.
725.0	1587.	690.0	107.	----	984.	----	0.826	284.	1536.8	P	0.470		547.
0.000406	0.000086	0.000152	0.000053	0.01633	0.00017	0.00826	0.000370	----	----	----	0.500	0.007	0.776
0.989	127.95	1357.6	16285.	5000.	149.1	1509.7	P	138.4	0.347	0.057	-2.9	.11799	1836.
725.0	1578.	690.0	106.	----	981.	----	0.826	284.	1536.4	P	0.469		546.
0.000405	0.000084	0.000152	0.000052	0.01626	0.00015	0.00821	0.000369	----	----	----	0.500	0.007	0.774
1.090	142.95	1484.8	16156.	5000.	149.1	1507.7	P	138.4	0.347	0.056	-2.9	.11832	1826.
725.0	1569.	690.0	106.	----	977.	----	0.826	284.	1536.0	P	0.469		546.
0.000403	0.000083	0.000152	0.000052	0.01620	0.00014	0.00815	0.000369	----	----	----	0.500	0.007	0.772
1.137	150.00	1544.4	16099.	5000.	149.1	1506.8	P	138.4	0.347	0.056	-2.9	.11847	1822.
725.0	1565.	690.0	106.	----	976.	----	0.826	284.	1535.7	P	0.468		545.
0.000402	0.000082	0.000152	0.000051	0.01616	0.00014	0.00813	0.000368	----	----	----	0.500	0.007	0.772

CLIMB TO 5000. FT. WITH MAXIMUM R/C AT NORMAL ENGINE RAT
** TAS(AND EAS) IS THE HORIZONTAL COMPONENT OF THE FLIGHT PATH

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	EAS (KTS)	MU	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	GAMMA (DEG)	BHP	R/C (FPM)
M.ROTOR VTIP (FPS)	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP PROP	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PERF		AUX. ENG. BHP OR THRUST	
CPPRO	CPINC	CPPAR	CPNUD	CDO	DELCDS	DELCDM	CXR	J	CP	CT	CLW	CDW	KN	
0.486	60.00	760.6	16882.	0.	76.4	1856.0	T	76.4	0.180	0.063	-2.4	7.3	1949.	1012.
725.0	1121.	650.0	64.	----	896.	----	0.820	0.	1856.0	T	0.835		0.	
0.000152	0.000200	0.000061	0.000011	0.00830	0.00000	0.00047	0.000332	----	----	----	0.300	0.007	0.959	
0.494	60.64	768.0	16875.	500.	76.4	1856.0	T	75.9	0.180	0.064	-2.3	7.1	1928.	976.
725.0	1123.	650.0	64.	----	885.	----	0.820	0.	1856.0	T	0.837		0.	
0.000153	0.000206	0.000061	0.000011	0.00834	0.00000	0.00051	0.000333	----	----	----	0.300	0.007	0.960	
0.503	61.30	775.5	16868.	1000.	76.4	1856.0	T	75.3	0.180	0.065	-2.3	6.8	1907.	935.
725.0	1125.	650.0	63.	----	874.	----	0.820	0.	1856.0	T	0.838		0.	
0.000154	0.000213	0.000061	0.000011	0.00838	0.00000	0.00055	0.000334	----	----	----	0.300	0.007	0.960	
0.512	61.99	783.3	16860.	1500.	77.4	1856.0	T	75.7	0.183	0.066	-2.3	6.5	1887.	902.
725.0	1129.	650.0	63.	----	864.	----	0.820	0.	1856.0	T	0.840		0.	
0.000156	0.000216	0.000063	0.000012	0.00845	0.00000	0.00062	0.000342	----	----	----	0.300	0.007	0.960	
0.521	62.71	791.3	16852.	2000.	77.4	1856.0	T	75.2	0.183	0.067	-2.3	6.2	1866.	864.
725.0	1132.	650.0	63.	----	853.	----	0.820	0.	1856.0	T	0.841		0.	
0.000157	0.000223	0.000064	0.000012	0.00850	0.00001	0.00067	0.000343	----	----	----	0.300	0.007	0.960	
0.531	63.47	799.5	16844.	2500.	77.4	1856.0	T	74.6	0.183	0.068	-2.3	5.9	1846.	825.
725.0	1135.	650.0	62.	----	842.	----	0.820	0.	1856.0	T	0.843		0.	
0.000157	0.000230	0.000064	0.000012	0.00855	0.00001	0.00071	0.000344	----	----	----	0.300	0.007	0.961	
0.541	64.26	808.0	16835.	3000.	78.4	1856.0	T	75.0	0.185	0.069	-2.3	5.6	1825.	786.
725.0	1140.	650.0	62.	----	832.	----	0.820	0.	1856.0	T	0.844		0.	
0.000160	0.000233	0.000066	0.000013	0.00864	0.00001	0.00080	0.000352	----	----	----	0.300	0.007	0.960	
0.551	65.11	816.8	16826.	3500.	78.4	1856.0	T	74.5	0.185	0.070	-2.3	5.3	1804.	747.
725.0	1144.	650.0	62.	----	821.	----	0.820	0.	1856.0	T	0.846		0.	
0.000161	0.000240	0.000066	0.000013	0.00870	0.00001	0.00086	0.000353	----	----	----	0.300	0.007	0.961	
0.563	65.99	826.0	16817.	4000.	79.4	1856.0	T	74.8	0.187	0.071	-2.3	5.0	1784.	707.
725.0	1149.	650.0	62.	----	811.	----	0.820	0.	1856.0	T	0.847		0.	
0.000163	0.000244	0.000069	0.000013	0.00881	0.00002	0.00096	0.000361	----	----	----	0.300	0.007	0.961	
0.574	66.94	835.5	16807.	4500.	79.4	1856.0	T	74.3	0.187	0.072	-2.3	4.7	1763.	666.
725.0	1153.	650.0	62.	----	801.	----	0.820	0.	1856.0	T	0.849		0.	
0.000165	0.000252	0.000069	0.000013	0.00887	0.00002	0.00102	0.000362	----	----	----	0.300	0.007	0.961	
0.587	67.95	845.5	16797.	5000.	79.4	1856.0	T	73.7	0.187	0.073	-2.2	4.4	1743.	626.
725.0	1158.	650.0	61.	----	790.	----	0.820	0.	1856.0	T	0.850		0.	
0.000166	0.000260	0.000069	0.000014	0.00894	0.00003	0.00109	0.000364	----	----	----	0.300	0.007	0.962	

TRANSFER ALTITUDE TO 1000. FT.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)
1.137	150.00	1544.4	16099.	5000.
1.137	150.00	1544.4	16099.	1000.

TAKEOFF, HOVER, OR LAND AT T/W = 1.060 FOR 0.200 HRS.

TIME (HRS) / M.ROTOR VTIP	RANGE (N.M.) / M.ROTOR RHP	FUEL USED (LBS) / T.ROTOR VTIP (FPS)	WEIGHT (LBS.) / T.ROTOR RHP	PRES. ALT. (FT) / VRC RHP	TAS (KTS) / PRIM.ENG FUEL FLOW (LBS/HR)	PRIM. TURB. TEMP. (R) / AUX.ENG FUEL FLOW (LBS/HR)	PRIM. ENG. CODE / ROTLI CODE	TOTAL FUEL FLOW (LBS/HR) / TEMP DEG. (F)	THRUST TO WEIGHT / DELDCM	FM / FMI	BHP / CPPRC	CT / CPIND	CT/SIGMA / CDC
1.137	150.00	1544.4	16099.	1000.	0.0	1633.1	P	1390.	1.060	0.709	2544.	0.0088	0.068
725.0	2101.	690.0	270.	0.	1298.	92.	A	55.4	0.0	0.709	0.00011	0.0071	0.0068
1.157	150.00	1572.1	16071.	1000.	0.0	1631.9	P	1387.	1.060	0.709	2538.	0.0088	0.068
725.0	2095.	690.0	269.	0.	1295.	92.	A	55.4	0.0	0.709	0.00011	0.0071	0.0068
1.177	150.00	1599.9	16043.	1000.	0.0	1630.6	P	1385.	1.060	0.709	2531.	0.0087	0.068
725.0	2090.	690.0	268.	0.	1293.	92.	A	55.4	0.0	0.709	0.00011	0.0071	0.0068
1.197	150.00	1627.6	16015.	1000.	0.0	1629.4	P	1383.	1.060	0.709	2524.	0.0087	0.068
725.0	2084.	690.0	267.	0.	1291.	92.	A	55.4	0.0	0.709	0.00011	0.0070	0.0068
1.217	150.00	1655.3	15988.	1000.	0.0	1628.2	P	1380.	1.060	0.709	2517.	0.0087	0.068
725.0	2079.	690.0	266.	0.	1288.	92.	A	55.4	0.0	0.709	0.00011	0.0070	0.0068
1.237	150.00	1682.9	15960.	1000.	0.0	1627.0	P	1378.	1.060	0.709	2511.	0.0087	0.068
725.0	2073.	690.0	265.	0.	1286.	92.	A	55.4	0.0	0.709	0.00011	0.0070	0.0068
1.257	150.00	1710.4	15933.	1000.	0.0	1625.8	P	1376.	1.060	0.709	2504.	0.0087	0.068
725.0	2067.	690.0	264.	0.	1284.	92.	A	55.4	0.0	0.709	0.00011	0.0070	0.0068
1.277	150.00	1737.9	15905.	1000.	0.0	1624.6	P	1374.	1.060	0.709	2497.	0.0087	0.068
725.0	2062.	690.0	263.	0.	1282.	92.	A	55.4	0.0	0.709	0.00011	0.0070	0.0068
1.297	150.00	1765.4	15878.	1000.	0.0	1623.4	P	1371.	1.060	0.709	2490.	0.0086	0.068
725.0	2056.	690.0	262.	0.	1279.	92.	A	55.4	0.0	0.709	0.00011	0.0069	0.0068
1.317	150.00	1792.8	15850.	1000.	0.0	1622.2	P	1369.	1.060	0.709	2484.	0.0086	0.067
725.0	2051.	690.0	261.	0.	1277.	92.	A	55.4	0.0	0.709	0.00011	0.0069	0.0068
1.337	150.00	1820.2	15823.	1000.	0.0	1621.0	P	1367.	1.060	0.709	2477.	0.0086	0.067
725.0	2045.	690.0	260.	0.	1275.	92.	A	55.4	0.0	0.709	0.00011	0.0069	0.0068
1.337	150.00	1820.2	15823.	1000.	0.0	1621.0	P	1367.	1.060	0.709	2477.	0.0086	0.067
725.0	2045.	690.0	260.	0.	1275.	92.	A	55.4	0.0	0.709	0.00011	0.0069	0.0068

CHANGE PAYLOAD, REMOVE 1000. LB.

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)
1.337	15C.CC	182C.2	15823.	1000.
1.347	15C.CC	1820.2	14823.	1000.

LOITER FOR 0.500 HRS.

TIME (HRS) M.ROTOR VTIP (FPS) CPFRC	RANGE (N.M.) M.ROTOR RHP CPINC	FUEL USED (LBS) T.ROTOR VTIP (FPS) CPF/R	WEIGHT (LBS.) T.ROTOR RPM CPNUD	PRES. ALT. (FT) PROP VTIP (FPS) CDO	TAS (KTS) PRIM.ENG FUEL FLOW (LBS/HR) DELCDS	PRIM. TURB. TEMP. (R) BHP AUX DELCDM	PRIM. ENG. CODE ETAP PRCP CXR	EAS (KTS) AUX. ENG. FUEL FLOW (LBS/HR) J	MU AUX. TURB. TEMP. CP	CT PRIME OVER SIGMA AUX. ENG. CODE CT	ALPHA D/L (DEG) AUX. ENG. PERF CLW	TOTAL FUEL FLOW (LBS/HR) CDW	BHP AUX. ENG. BHP OR THRUST RN
1.347 725.0 0.000150	150.00 906. 0.000162	1820.2 690.0 0.000033	14823. 57. 0.000009	1000. ---- 0.00822	75.6 813. 0.0	1375.0 ---- 0.00039	P 0.839 0.000183	74.5 155. ----	0.176 1207.7 ----	0.056 P ----	-1.5 0.044 0.400	967. 0.007	1093. 55. 0.942
1.397 725.0 0.000150	150.00 903. 0.000160	1868.6 690.0 0.000033	14774. 57. 0.000009	1000. ---- 0.00822	75.6 812. 0.0	1374.4 ---- 0.00038	P 0.839 0.000183	74.5 155. ----	0.176 1207.6 ----	0.056 P ----	-1.5 0.044 0.400	966. 0.007	1090. 55. 0.942
1.447 725.0 0.000150	150.00 900. 0.000159	1916.9 690.0 0.000033	14726. 57. 0.000009	1000. ---- 0.00822	75.6 811. 0.0	1373.8 ---- 0.00038	P 0.839 0.000183	74.5 155. ----	0.176 1207.6 ----	0.056 P ----	-1.5 0.043 0.400	965. 0.007	1087. 55. 0.942
1.497 725.0 0.000150	150.00 897. 0.000158	1965.2 690.0 0.000033	14678. 57. 0.000009	1000. ---- 0.00822	75.6 810. 0.0	1373.2 ---- 0.00038	P 0.839 0.000183	74.5 155. ----	0.176 1207.6 ----	0.056 P ----	-1.5 0.043 0.400	964. 0.007	1083. 55. 0.942
1.547 725.0 0.000150	150.00 894. 0.000157	2013.4 690.0 0.000033	14630. 57. 0.000009	1000. ---- 0.00821	75.6 809. 0.0	1372.6 ---- 0.00038	P 0.839 0.000183	74.5 155. ----	0.176 1207.5 ----	0.055 P ----	-1.5 0.043 0.400	963. 0.007	1080. 55. 0.942
1.597 725.0 0.000150	150.00 891. 0.000156	2061.6 690.0 0.000033	14581. 57. 0.000009	1000. ---- 0.00821	75.6 808. 0.0	1372.0 ---- 0.00038	P 0.839 0.000183	74.5 155. ----	0.176 1207.5 ----	0.055 P ----	-1.5 0.043 0.400	962. 0.007	1077. 55. 0.941
1.647 725.0 0.000150	150.00 888. 0.000155	2109.7 690.0 0.000032	14533. 57. 0.000009	1000. ---- 0.00821	75.6 807. 0.0	1371.4 ---- 0.00037	P 0.839 0.000182	74.5 155. ----	0.176 1207.4 ----	0.055 P ----	-1.5 0.043 0.400	961. 0.007	1074. 55. 0.941
1.697 725.0 0.000150	150.00 885. 0.000154	2157.7 690.0 0.000032	14485. 56. 0.000009	1000. ---- 0.00821	75.6 806. 0.0	1370.8 ---- 0.00037	P 0.839 0.000182	74.5 155. ----	0.176 1207.4 ----	0.055 P ----	-1.5 0.043 0.400	960. 0.007	1070. 54. 0.941
1.747 725.0 0.000149	150.00 883. 0.000155	2205.7 690.0 0.000031	14437. 56. 0.000009	1000. ---- 0.00818	74.6 805. 0.0	1370.5 ---- 0.00035	P 0.839 0.000179	73.5 154. ----	0.174 1206.2 ----	0.055 P ----	-1.5 0.042 0.400	959. 0.007	1068. 53. 0.942
1.797 725.0 0.000149	150.00 879. 0.000154	2253.7 690.0 0.000031	14389. 56. 0.000009	1000. ---- 0.00818	74.6 804. 0.0	1369.9 ---- 0.00035	P 0.839 0.000178	73.5 154. ----	0.174 1206.2 ----	0.055 P ----	-1.5 0.042 0.400	958. 0.007	1065. 53. 0.942
1.847 725.0 0.000149	150.00 876. 0.000153	2301.6 690.0 0.000031	14341. 56. 0.000009	1000. ---- 0.00818	74.6 803. 0.0	1369.3 ---- 0.00034	P 0.839 0.000178	73.5 154. ----	0.174 1206.2 ----	0.054 P ----	-1.5 0.042 0.400	957. 0.007	1061. 53. 0.942

CLIMB TO 3000. FT. WITH MAXIMUM R/C AT NORMAL ENGINE RAT
** TAS(AND EAS) IS THE HORIZONTAL COMPONENT OF THE FLIGHT PATH

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	EAS (KTS)	MU	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	GAMMA (DEG)	BHP	R/C (FPM)
M.ROTOR VTIP (FPS)	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	PROF VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP FRCP	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PERF		AUX. ENG. BHP OR THRUST	
CPFRC	CPINC	CPPAR	CPNUD	CDO	DELCDS	DELCDM	CXR	J	CP	CT	CLW	CDW	RN	
1.847	150.00	2301.6	14341.	1000.	71.5	1856.0	T	70.5	0.169	0.055	-2.6	11.0	1905.	1469.
725.0	943.	690.0	56.	----	874.	----	0.820	0.	1856.0	T	0.838		0.	
0.000147	0.000159	0.000054	0.000008	0.00813	0.0	0.00030	0.000317	----	----	----	0.400	0.007	0.945	
1.853	150.41	2306.6	14336.	1500.	71.5	1856.0	T	69.9	0.169	0.055	-2.6	11.0	1884.	1429.
725.0	943.	690.0	57.	----	863.	----	0.820	0.	1856.0	T	0.840		0.	
0.000147	0.000164	0.000054	0.000008	0.00815	0.0	0.00033	0.000318	----	----	----	0.400	0.007	0.946	
1.859	150.83	2311.6	14331.	2000.	72.5	1856.0	T	70.4	0.171	0.056	-2.6	10.6	1864.	1389.
725.0	945.	690.0	57.	----	852.	----	0.820	0.	1856.0	T	0.841		0.	
0.000149	0.000166	0.000056	0.000009	0.00820	0.0	0.00038	0.000326	----	----	----	0.400	0.007	0.945	
1.865	151.28	2316.7	14326.	2500.	72.5	1856.0	T	69.9	0.171	0.057	-2.6	10.3	1843.	1349.
725.0	946.	690.0	57.	----	842.	----	0.820	0.	1856.0	T	0.843		0.	
0.000149	0.000171	0.000057	0.000009	0.00823	0.0	0.00041	0.000327	----	----	----	0.400	0.007	0.946	
1.871	151.73	2321.9	14321.	3000.	72.5	1856.0	T	69.4	0.171	0.058	-2.5	10.0	1823.	1308.
725.0	947.	690.0	56.	----	831.	----	0.820	0.	1856.0	T	0.844		0.	
0.000150	0.000177	0.000057	0.000009	0.00826	0.0	0.00044	0.000328	----	----	----	0.400	0.007	0.947	

CRUISE AT SPEED FOR 99 PER CENT BEST RANGE WITH HEADWIND OF 0.0

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	TAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	EAS (KTS)	MU	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	SPEC. RANGE (NMPP)	BHP
M.ROTOR VTIP (FPS)	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	RHP AUX	ETAP PROP	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PEFF		AUX. ENG. BHP OR THRUST
CPPRO	CPINC	CPFAR	CPNUO	CDO	DELCDS	DELCDM	CXR	J	CP	CT	CLW	CDW	RN
1.871	151.73	2321.9	14321.	3000.	150.1	1460.1	P	143.6	0.349	0.044	-2.8	.11817	1613.
725.0	1367.	650.0	100.	----	937.	----	0.826	335.	1609.1	P	0.547		672.
0.000361	0.000050	0.000114	0.000041	0.01443	0.00001	0.00652	0.000273	----	----	----	0.500	0.007	0.723
1.971	166.73	2448.9	14194.	3000.	150.1	1458.7	P	143.6	0.349	0.044	-2.8	.11842	1605.
725.0	1360.	650.0	100.	----	934.	----	0.826	334.	1608.7	P	0.547		672.
0.000360	0.000049	0.000114	0.000040	0.01438	0.00001	0.00647	0.000273	----	----	----	0.500	0.007	0.721
2.071	181.73	2575.5	14067.	3000.	150.1	1457.3	P	143.6	0.349	0.043	-2.8	.11867	1597.
725.0	1353.	650.0	100.	----	932.	----	0.826	334.	1608.2	P	0.546		671.
0.000359	0.000048	0.000113	0.000040	0.01434	0.00001	0.00643	0.000273	----	----	----	0.500	0.007	0.718
2.171	196.73	2701.9	13941.	3000.	150.1	1455.9	P	143.6	0.349	0.042	-2.9	.11892	1590.
725.0	1346.	650.0	99.	----	929.	----	0.826	334.	1607.7	P	0.546		670.
0.000357	0.000047	0.000113	0.000039	0.01429	0.00000	0.00639	0.000272	----	----	----	0.500	0.007	0.716
2.271	211.73	2828.1	13815.	3000.	150.1	1454.6	P	143.6	0.349	0.042	-2.9	.11917	1582.
725.0	1339.	650.0	99.	----	927.	----	0.826	334.	1607.2	P	0.545		670.
0.000356	0.000045	0.000113	0.000039	0.01425	0.00000	0.00634	0.000272	----	----	----	0.500	0.007	0.713
2.371	226.73	2953.9	13689.	3000.	150.1	1453.2	P	143.6	0.349	0.041	-2.9	.11941	1575.
725.0	1332.	650.0	99.	----	925.	----	0.826	333.	1606.8	P	0.544		669.
0.000355	0.000044	0.000113	0.000038	0.01420	0.00000	0.00630	0.000272	----	----	----	0.500	0.007	0.711
2.471	241.73	3079.6	13563.	3000.	150.1	1451.9	P	143.6	0.349	0.041	-3.0	.11966	1568.
725.0	1325.	650.0	99.	----	922.	----	0.826	333.	1606.3	P	0.544		668.
0.000354	0.000043	0.000113	0.000038	0.01416	0.00000	0.00626	0.000271	----	----	----	0.500	0.007	0.708
2.571	256.73	3204.9	13438.	3000.	150.1	1450.6	P	143.6	0.349	0.040	-3.0	.11990	1561.
725.0	1318.	650.0	99.	----	920.	----	0.826	333.	1605.8	P	0.543		667.
0.000353	0.000042	0.000113	0.000037	0.01412	0.00000	0.00622	0.000271	----	----	----	0.500	0.007	0.705
2.670	271.73	3330.0	13313.	3000.	150.1	1449.3	P	143.6	0.349	0.040	-3.0	.12015	1553.
725.0	1312.	650.0	98.	----	918.	----	0.826	333.	1605.3	P	0.543		667.
0.000352	0.000041	0.000113	0.000037	0.01408	0.00000	0.00617	0.000271	----	----	----	0.500	0.007	0.703
2.770	286.73	3454.9	13188.	3000.	150.1	1448.0	P	143.6	0.349	0.039	-3.1	.12038	1546.
725.0	1305.	650.0	98.	----	916.	----	0.826	332.	1604.9	P	0.542		666.
0.000351	0.000040	0.000113	0.000036	0.01403	0.00000	0.00613	0.000271	----	----	----	0.500	0.007	0.700
2.859	300.00	3565.1	13076.	3000.	150.1	1446.9	P	143.6	0.349	0.039	-3.1	.12060	1540.
725.0	1299.	650.0	98.	----	914.	----	0.826	332.	1604.5	P	0.542		665.
0.000350	0.000039	0.000112	0.000036	0.01400	0.00000	0.00610	0.000270	----	----	----	0.500	0.007	0.697

LOITER FOR 0.250 HRS. FOR RESERVE FUEL

TIME (HRS)	RANGE (N.M.)	FUEL USED (LBS)	WEIGHT (LBS.)	PRES. ALT. (FT)	IAS (KTS)	PRIM. TURB. TEMP. (R)	PRIM. ENG. CODE	EAS (KTS)	MU	CT PRIME OVER SIGMA	ALPHA D/L (DEG)	TOTAL FUEL FLOW (LBS/HR)	BHP
M.ROTOR VTIP (FPS)	M.ROTOR RHP	T.ROTOR VTIP (FPS)	T.ROTOR RHP	PROP VTIP (FPS)	PRIM.ENG FUEL FLOW (LBS/HR)	BHP AUX	ETAP PROP	AUX. ENG. FUEL FLOW (LBS/HR)	AUX. TURB. TEMP.	AUX. ENG. CODE	AUX. ENG. PERF		AUX. ENG. BHP OR THRUST
CPFFO	CPINC	CPPAR	CPNUD	CDO	DELCDS	DELCDM	CXR	J	CP	CT	CLW	CDW	RN
2.859	300.00	3565.1	13078.	3000.	73.1	1361.3	P	69.9	0.170	0.053	-2.2	835.	1022.
725.0	841.	690.0	53.	----	758.	----	0.839	78.	852.1	P	0.0		0.
0.000148	0.000140	0.000045	0.000008	0.00820	0.0	0.00037	0.000264	----	----	----	0.400	0.00[illegible]	0.943
2.909	300.00	3606.9	13036.	3000.	73.1	1360.8	P	69.9	0.170	0.052	-2.3	835.	1019.
725.0	839.	690.0	53.	----	757.	----	0.839	78.	852.1	P	0.0		0.
0.000148	0.000145	0.000045	0.000008	0.00820	0.0	0.00037	0.000264	----	----	----	0.400	0.007	0.942
2.959	300.00	3648.6	12994.	3000.	73.1	1360.3	P	69.9	0.170	0.052	-2.3	834.	1017.
725.0	836.	690.0	53.	----	756.	----	0.839	78.	852.1	P	0.0		0.
0.000148	0.000144	0.000045	0.000008	0.00820	0.0	0.00036	0.000263	----	----	----	0.400	0.007	0.942
3.009	300.00	3690.3	12953.	3000.	73.1	1359.7	P	69.9	0.170	0.052	-2.3	833.	1014.
725.0	833.	690.0	53.	----	755.	----	0.839	78.	852.1	P	0.0		0.
0.000149	0.000143	0.000045	0.000008	0.00820	0.0	0.00036	0.000263	----	----	----	0.400	0.007	0.942
3.059	300.00	3731.9	12911.	3000.	73.1	1359.2	P	69.9	0.170	0.052	-2.3	832.	1011.
725.0	831.	690.0	53.	----	755.	----	0.839	78.	852.1	P	0.0		0.
0.000148	0.000142	0.000045	0.000008	0.00820	0.0	0.00036	0.000263	----	----	----	0.400	0.007	0.942
3.109	300.00	3773.5	12869.	3000.	72.1	1358.6	P	69.0	0.168	0.052	-2.2	831.	1008.
725.0	828.	690.0	53.	----	754.	----	0.839	78.	852.1	P	0.0		0.
0.000147	0.000144	0.000044	0.000007	0.00817	0.0	0.00034	0.000258	----	----	----	0.400	0.007	0.943

MISSION FUEL REQUIRED = 3565.08
RESERVE FUEL REQUIRED = 208.46
TOTAL FUEL REQUIRED = 3773.53

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